PRODUCT ENGINEERING

JUNE 1950

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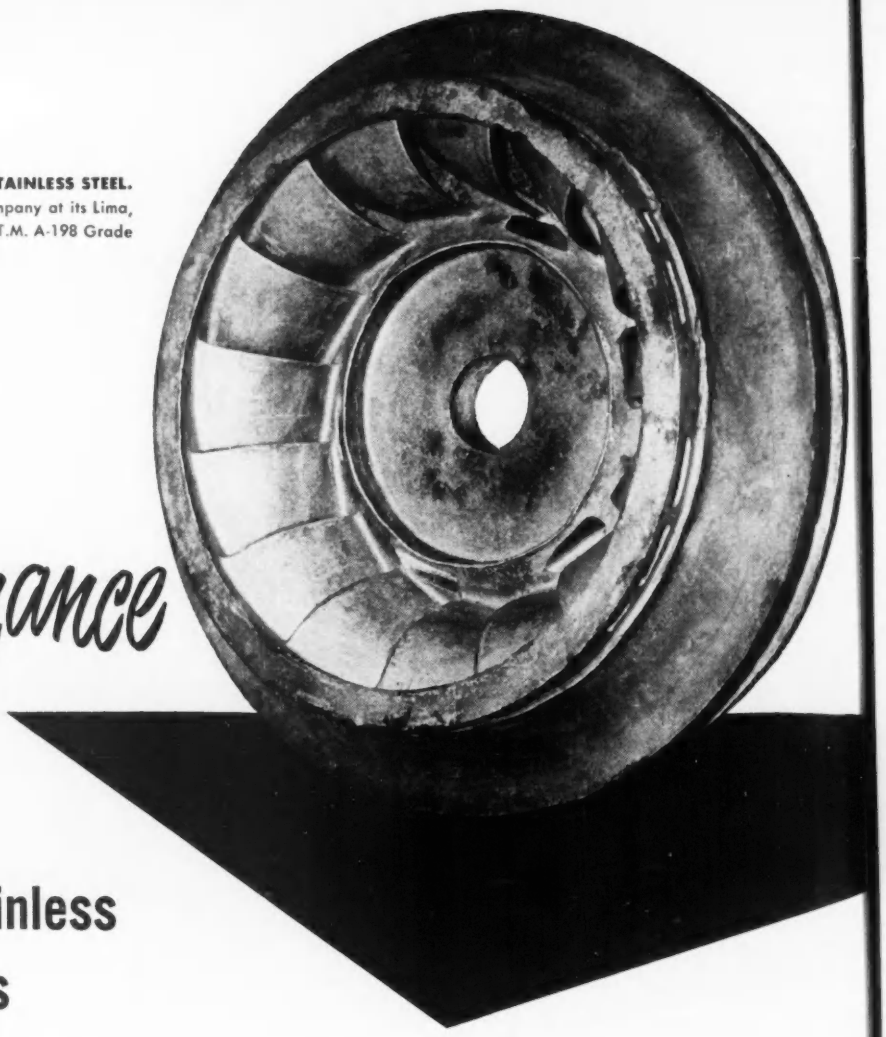

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NUMBER 7

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JULY 1950

An Engineering Approach to Cost Reduction by D. C. Peterson 81
How a product analysis section in the engineering department systematically reduces costs.

Selecting a Metallic Bellows by A. H. Ellis and J. H. Howard 86
How type of application, material, and other factors affect operating characteristics and life.

Product Designs 90
Air compressor; New Fiat car; Control system for color printing press; Bottle uncaser.

Nylon in Bearings and Gears by William C. Wall 102
Results of performance tests and typical mechanical applications of molded nylon.

Critical Buckling Loads for Hydraulic Actuating Cylinders by Fred Hoblit 108
Buckling loads for columns where fluid pressure transmits the load over part of column length.

Variable Reactors and Differential Transformers by T. R. Breunich 113
Use of these elements in control or indicating circuits for sensing small motions.

Face Gear Design Factors by Victor Francis and Joseph Silvagi 117
Data for calculating the principal dimensions of on-center face gears of different pressure angles.

Standards Programs and Procedure by George E. Rowbotham 122
Scope of a standards program, organization structure and type of approach for efficient operation.

Fatigue Properties of Aluminum Alloys by R. L. Templin, F. M. Howell, E. C. Hartmann... 126
Designers cannot apply the results of static mechanical tests to fatigue-stressed structures.

Magnetic Powder Clutches Speed Servo Response 131
Describes the performance of a typical remote positioner using such clutches.

How to Connect Tubing—Cross and Tee Joints 134
Construction details of various types of welded and mechanical joints.

Kinematics of the Crank and Slot Drive by S. Rappaport 136
A low-cost substitute for elliptical gearing.

General Properties of Plastic Materials by Wyman Goss 149
Physical, chemical and electrical properties of a wide range of commonly used plastics.

Highlights 3
This Month's Cover 7
Editorial 79
Engineering Abstracts 139
Technical News 142
New Components, Parts, and Materials 154
New Catalogs and Bulletins 190
Meetings 196
Our Readers Say 198
New Books 208

FOR MORE INFORMATION: READER SERVICE CARD PAGE 176

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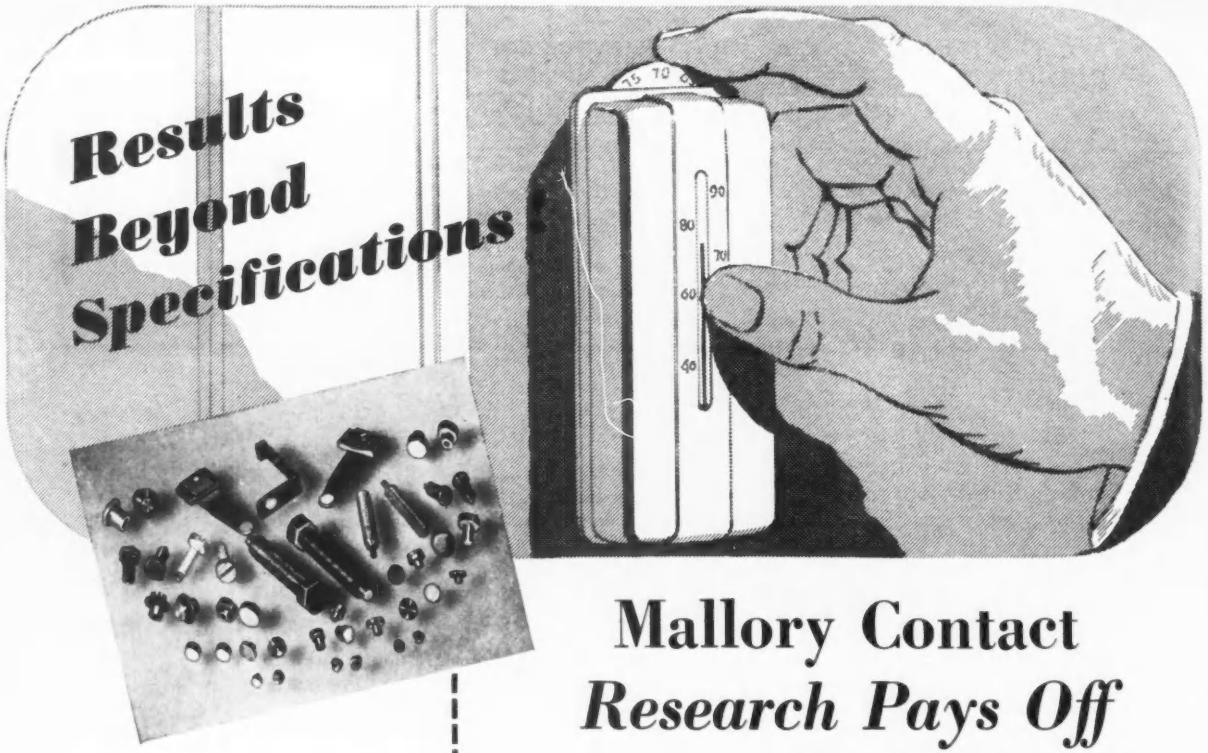

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An Engineering Approach To Cost Reduction

COORDINATION of engineering and manufacturing department problems through periodic conferences facilitate designs that are easier and less costly to produce. The author is seated at center.

D. C. PETERSON

Director of Engineering and Manufacturing
Stewart-Warner Corporation

THE ENGINEER is primarily interested in the end use of his product design—more so than in the problems of manufacture or cost limitations. Realizing this, it was apparent that a separate entity would be necessary to analyze product designs with regard to manufacturing processes and cost reduction possibilities. The result of this thinking in the Stewart-Warner Corporation was the establishment within the Engineering Division (Fig. 1) of the Product Analysis Engineering Department.

This department is made up of a department head, who reports directly to the director of engineering, four product analysis engineers, two liaison engineers, and a coordinator for engineering changes. The basic function and responsibility of this department is carrying out the program for cost reduction by analysis of product designs. The specific functions assigned to this department are: (1) Analysis of new product designs prior to release for production, (2) analysis of current products for cost reduction possibilities, (3) screening and coordinating engineering changes, (4) establishment of design data for the engineering manual, (5) design consultation, (6) coordination of engineering and manufacturing problems, (7) evaluation of suggestions submitted by employees pertaining to product design, and (8) special projects assigned by the director of engineering.

The product analysis department systematically screens every product

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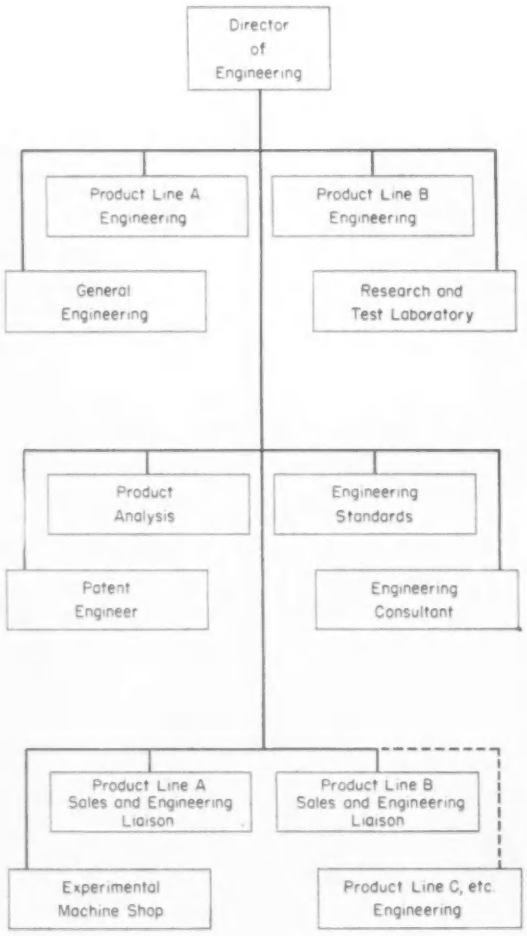
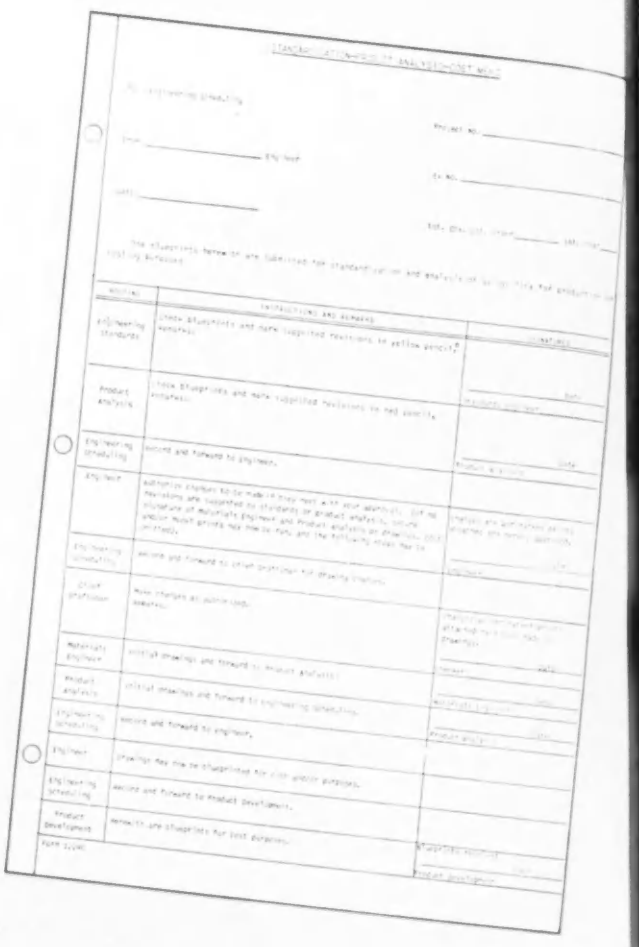


1 Organization of the Stewart-Warner Engineering Division is set up on a departmental basis. The engineering of entire product lines is entrusted to separate product design departments, which are further subdivided into project sections.



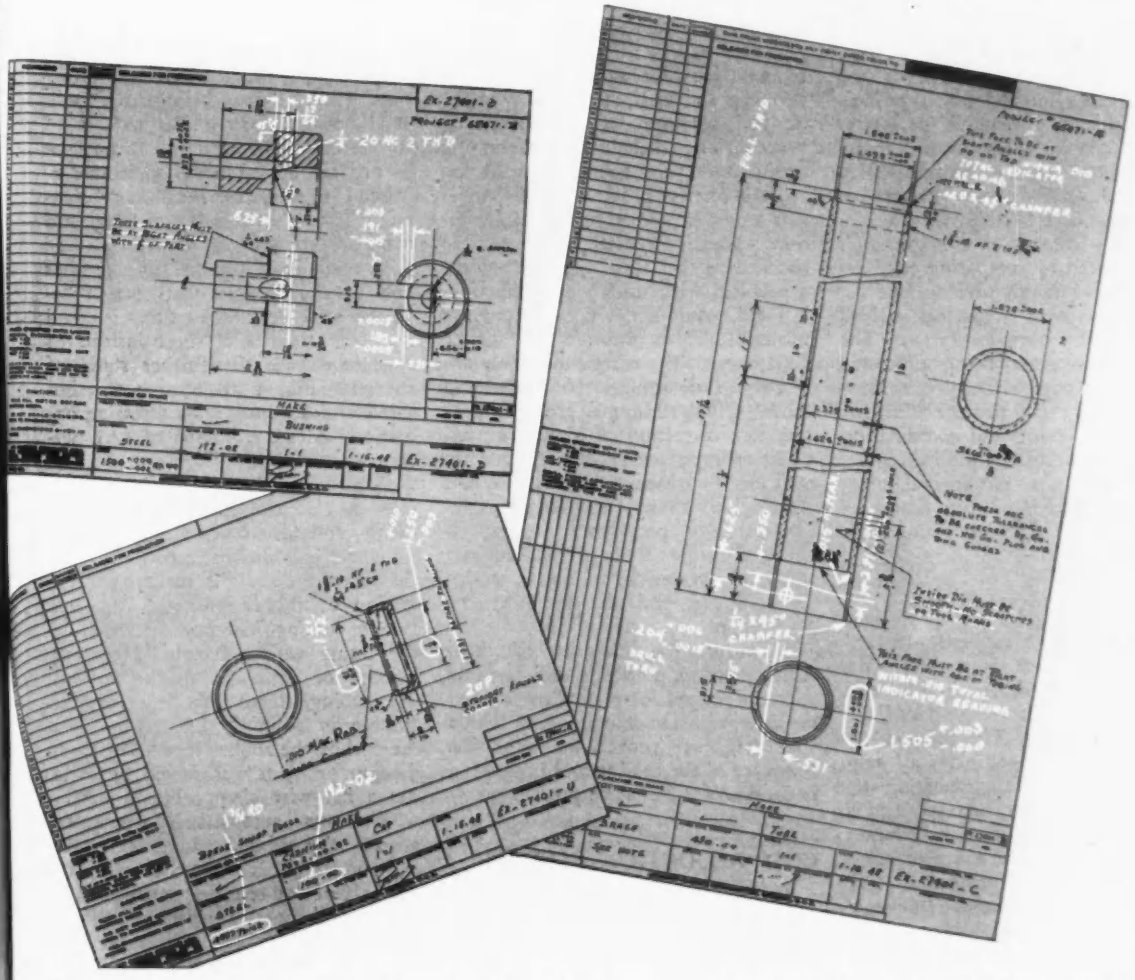
2 Engineering routing form is used to release a product design for analysis. Accompanied by a complete set of blueprints, this form is routed through the standards engineer, the product analysis department, and the project engineer.

design, breaking it down to its simplest components for cost reduction and manufacturing process analysis. A product design is released for analysis by means of an engineering routing form (Fig. 2) accompanied by a complete set of blueprints. The standards engineer examines the usage of common parts, materials, gages, finishes, and nomenclature for conformity to established company standards. The blueprints then are routed to the product analysis department for their study. The overall design, every assembly, and each detail is critically analyzed and the individual prints are marked with recommendations to meet the following objectives:

1. Simplification of design, to facilitate production and service.
2. Fabrication of parts and assembly by more economical methods.
3. Use of standard and/or current production parts, to avoid the need for new tooling.
4. Prevent or minimize causes for possible field complaints.
5. Improvement in product quality, by revising material and processing specifications.
6. Use of a different material where feasible to lower unit cost.

The blueprints (Fig. 3) are then returned to the project engineer for his review and approval of the recommended revisions. At this point, it is general practice for the project and product analysis engineers to review the design together. Further, if differences of opinion arise at this point, cost estimating, tooling, and processing representatives are brought into the discussion and firm decisions are made on detail of design that will facilitate production. The drawings are changed and forwarded to the product analysis department for signature.

In "screening" a design, those parts which offer the best cost reduction possibilities are analyzed thoroughly first. Later, when the complete design has been analyzed, these parts are reviewed again and, if possible, ideas are further expanded. By this method, every opportunity for cost reduction is taken. When considering purchased parts, the purchasing department is required to follow through any cost reduction possibilities with suppliers. Close cooperation of engineering with suppliers can prove to be especially fruitful in the design stage. It gives the vendor an opportunity to parallel the development of his product, when a standard part cannot be used, with the new product design.



3 Blueprint of the part accompanies the routing form through the product analysis department, and are returned to the project engineer marked with recommended revisions. After such recommendations are marked on the blueprints, it is common practice for the project and product analysis engineers to review the design together. If differences of opinion arise, other departments are brought into the discussion. All drawing changes must be approved by the product analysis department.

DESIGN CONSULTATION

As a service function of a staff nature, various sections of the manufacturing division periodically confer with the product analysis department on design and manufacturing methods problems, suggesting alternate methods that are less costly if minor revisions can be made on the part. These consultations help to: (1) Weed out impractical ideas; (2) design parts for economical production; (3) utilize the best manufacturing processes; (4) initiate more "common sense" design; (5) set a pattern for standardization.

ENGINEERING DESIGN MANUAL

The use of effective standards is one of engineering management's most reliable tools. Every design standard that can be initiated and put into practice reduces the number of production conferences, prevents controversies, reduces the possibility of engineering and factory errors, and helps relieve unnecessary pressure on management.

Design standards and drafting practice instructions are initiated by the product analysis department. These include such typical items as (1) standard sizes and tolerances for punched and drilled holes, (2) dimensioning holes in die castings for straight and taper thread tapping, (3) machine surface finishes, (4) ball seat swaging, (5) dimensions and tolerances for pistons and cylinders used in hydraulic applications. The standards engineer issues and maintains the printed standards in their final form, and acts as coordinator between the chief draftsman and the product analysis department. The standards engineer initiates raw material, heat treatment, and processing specifications and institutes tabulated lists of preferred common parts such as screws, bolts, nuts, washers, rivets and pins. Development and institution of design standards in the engineering department is further reflected by the standardization that takes place in other divisions of the company.

ENGINEERING CHANGES

In this phase all engineering changes are screened and coordinated. Since changes cost money in holding up production, revising tools, reworking of parts, and scrapping of processed stock, the engineering department takes the following precautions; (1) All requests for a change are in-

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vestigated to determine the need; (2) urgency of the request is determined; (3) disposition of stock is established; (4) the request is checked for conformity to established standards and manufacturing methods; (5) production is stopped whenever necessary; and (6) change requests are accumulated and combined to be released in conjunction with other changes or with groups of related parts.

The effectiveness of this phase is best illustrated by comparing two successive twelve-month periods, one before the institution of product analysis and the other after institution. The number of changes being processed through the engineering department was reduced by 45.9 percent. Further, by careful screening and coordinating of change requests, the product analysis department was instrumental in reducing the number of man hours required to make drawing changes by 31.8 percent.

SUGGESTION EVALUATION

In the employee suggestion award system practiced at Stewart-Warner, cash awards are paid, based on savings to the company that result from the accepted suggestion. The product analysis department investigates all suggestions pertaining to engineering design or specifications. Acceptance is based on (1) functional adaptation of the idea, (2) maintenance of engineering and design principles, (3) cost analysis comparisons, (4) raw material implications, (5) manufacturing methods, (6) production requirements, and (7) conformity to established standards.

A review of all these factors—often involved test samples made to "prove out" the idea—leads to a final decision. The suggestion is then accepted and a request for an engineering change is initiated, or rejected because it does not meet the applicable requirements, or referred to another department because the suggestion did not affect engineering design or specifications.

ENGINEERING AND MANUFACTURING

Manufacturing a diversity of products necessitates close coordination and cooperation between the engineering and manufacturing departments. The product analysis department, through its liaison engineers, maintains this coordination. Often its position is that of an arbitrator, impartially analyzing the problem from both sides, finding the source of trouble, and determining the proper remedy.

A typical request received by product analysis might be from a manufacturing department to investigate difficulties encountered in the production of a part or assembled unit. Such requests are thoroughly analyzed and revisions are made, if necessary, in the design, tooling, or manufacturing process. The results of this continuing coordination are best visible in the analysis of new product designs; parts that might encounter processing conditions already analyzed are double checked so that they will not become a problem when in actual production.

Field complaints are relayed to product analysis through the service department. These are thoroughly analyzed to determine the underlying cause. Often additional processing inspection, correction of tooling or fixtures, or improvement of a process are sufficient to remedy the cause. When the analysis shows that the engineering design or specification is the basic cause, a further study is made of the related parts, stock on hand, service requirements, and the feasibility of a redesign.

However, the majority of these manufacturing problems and possible sources for field complaints are weeded out in production pilot runs, in which the design is "proven out" and the adequacy of the tooling and processing is checked for full scale production.

COST REDUCTION STUDIES

The majority of products manufactured by a large organization undergo yearly changes because of customer model revisions, product improvement, or restyling with predominant trends. Cost reduction analyses are made on these changes as outlined previously in the discussion of analysis of product designs. There are, however, accessory products that are used with many of the major products which are not affected by the above changes. These "stable" products or parts offer the greatest possibilities for cost reduction through investigation by the product analysis department.

In a flexible shaft study, this department devoted its time to detail parts, and especially to the coupling nuts. In the first attempt to reduce costs, the material was changed from steel sheet to aluminum sheet on the large female coupling nut, resulting in cost reduction of 14.5 percent. However, in the pilot run some manufacturing difficulties were encountered. Analysis revealed that the design was the inherent cause, and to avoid using special fixtures and lowering production rates, the physical design of the part was changed. The redesigned coupling nut, Fig. 4, made from aluminum, enabled a better part to be produced, realizing a saving of 16.6 percent in the final analysis. Results obtained on the large nut encouraged study of the small female coupling nut. This part was being made from steel bar stock, so it was redesigned to conform with the large female nut in physical appearance, also from aluminum sheet stock. Again, a substantial reduction in cost was realized and a better product was achieved.

A male coupling nut at the other end of the flexible shaft was redesigned some years ago so that it could be made from steel sheet instead of steel bar stock. By further study of the part, Fig. 4, the design was improved, eliminating one processing operation. A cost reduction of 12.1 percent was effected.

Where flexible shafts are installed close to electrical terminals on instruments, and near other wiring connections for automobile accessories, the casing on the shaft is covered with a section of rubber tubing. This section of tubing had been fastened to the casing with a ferrule. However, because of variations in the size of the tubing, there was considerable trouble in slipping the ferrule over the end of the rubber tube. This production problem was solved by making a flat wire clamp, Fig. 5 (left) which was automatically wrapped around the rubber tubing, crimped, and cut off. This enabled a saving of one-half of one cent per flexible shaft.

Other changes in specific production methods resulted in cost savings. Electrical terminal studs on fuel lever tank units were being made of brass wire by the cold-heading process; secondary operations were necessary to drill, counterdrill, and tap a thread in the terminal, Fig. 5 (right). Analysis showed that this part could be made in one operation on an automatic screw machine and could be designed to be functionally equivalent to the cold-headed version. Samples were made which passed all tests successfully; the drawings were changed and a 23.2 percent cost reduction was achieved.

Working with suppliers on purchased parts to affect cost reductions has proven to be effective. When purchasing hard drawn copper wire brazing rings, 24 gage wire had been specified for the most popular ring sizes. The supplier suggested that the gage be changed from 24 to 22; this would increase the basic material cost but would decrease his forming charges. An average net saving of 21.9 percent resulted from adopting the supplier's recommendations.

Sometimes a combination of "home-

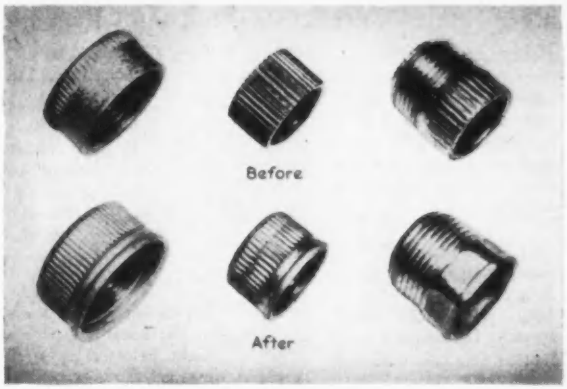

Fig. 4—Redesign of male coupling nut by product analysis department resulted in cost reduction of more than 10 percent. New design utilizes steel sheet instead of bar stock.

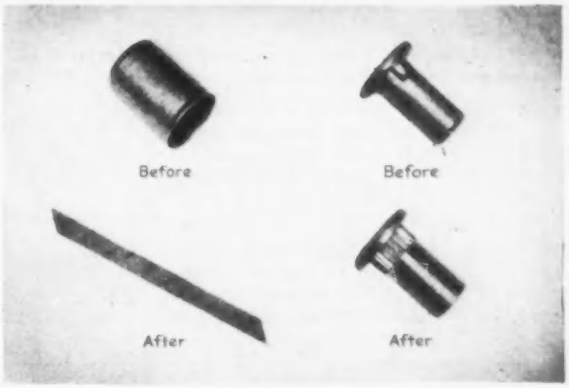

Fig. 5—(Left) Replacement of ferrule with a flat wire clamp made production easier. (Right) Secondary machining eliminated by redesigning cold-headed brass electrical terminal studs.

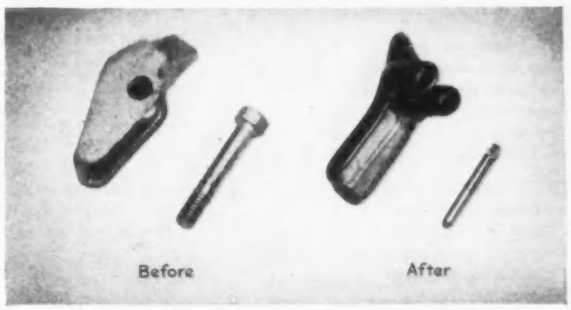

Fig. 6—Cost reduction of over 25 percent was realized by redesigning latch, formerly machined from a brass casting and assembled with special screw. New design utilizes heat treated steel stamping held in place by steel pin, raising production rates.

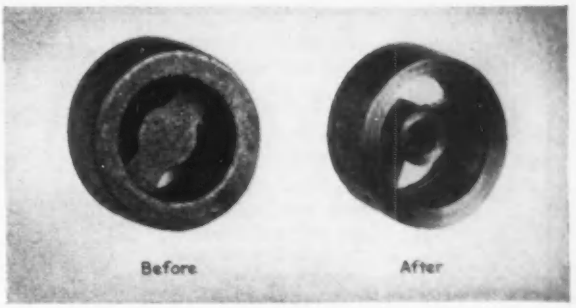

Fig. 7—Increased production rates, with concomitant reduction in manufacturing costs, were obtained by redesigning plunger body to be made on automatic screw machines from steel bar stock; formerly it was produced by hand from cast iron.

made" and purchased parts is the most economical solution to a problem. One such problem involved a tubing connection that was the source of leakage on a pumping unit. A nut, sleeve, and adaptor (purchased as a unit) was used to make the connection in the standard manner. After trying tubing connections from different sources with no improvement in the condition, the assembly was analyzed and the sleeve was found not to be functioning properly. The product analysis department designed a sleeve and made samples which proved to be satisfactory. The nut and adaptor were purchased to complete the unit. Total cost of the three parts was substantially less than the single unit formerly purchased.

An illustration of part redesign for cost reduction purposes is the latch shown in Fig. 6. This part was being machined from a brass casting, and was assembled with a special screw, involving special fixtures and machine setups which resulted in low rates of production. After several variations in design were mulled over, a heat treated steel stamping, to be held in place by a steel pin, was selected. Final analysis of cost figures on this unit revealed that a reduction of over 25 percent had been realized.

The plunger body shown in Fig. 7 gave a similar experience. This part was being machined from cast iron on a hand screw machine setup at low rates of production. After analysis, this part was made on an automatic screw machine from steel bar stock, with a secondary operation of piercing the slots on a punch press, thus achieving a sizable reduction in manufacturing costs.

PROCEDURE

Although Stewart-Warner does not presume to consider its product analysis engineering department a perfect "model", its method of operation should be of some interest to similar organizations. The initial step in cost reduction is a systematic study of the entire product line. After specific units are selected for further analysis, a breakdown of the unit is made to isolate those parts which carry potential cost reduction possibilities. Because the originality of the majority of these designs dates back quite a number of years, they can be reviewed in the light of new materials and new manufacturing processes.

When potential cost reduction ideas are localized to a specific part or assembly, the merits of the design change or material revision are discussed with the project engineer concerned. Joint conferences are often held with representatives of other departments, such as tooling, purchasing, cost and sales.

The next step, then, is to make cost comparisons. Drawings of the proposed design are prepared for a detailed cost analysis. The cost estimating department helps in this respect by furnishing comparative estimates of the basic elements of cost. These elements are (1) material, (2) labor, (3) overhead, and (4) tooling. Considerable weight is given to the problem of tool amortization in the cost analysis. A critical study of the cost analysis is made and, if all factors are in favor of the revised design, the project is approved and transferred to the project engineering section for preparation of production drawings, which are released to the manufacturing division.

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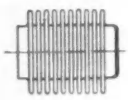
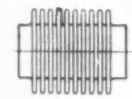
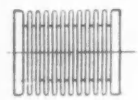
Common Types of Bellows and Methods of Attaching End Fittings



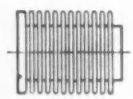
(A) Plain end bellows with one end closed and one without fittings. All convolutions are live.



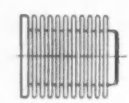
(B) Plain end bellows with both ends open. All convolutions are live, as with the previous type.



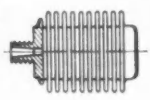
(C) Plain end bellows with both ends opened up to take fittings. The end convolutions are dead.



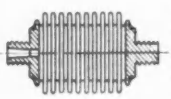
(D) Plain end bellows with both ends open, one on the fold. One end convolution is dead.



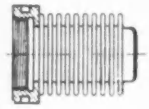
(E) Plain end bellows with one end closed and one end open on the fold. One end convolution is dead.



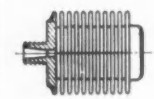
(F) Bellows with one end closed and one equipped with a fitting applied to the tube before the forming operation.



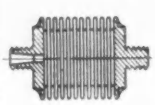
(G) Same as type (F) except that in this case fittings were applied to both ends before the forming operation.



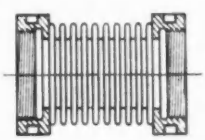
(H) Bellows with one closed and one open with a mechanical fitting attached to the open end.



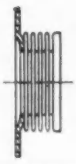
(K) Same as type (E) but with an end fitting or head spun into the opened convolution after forming.



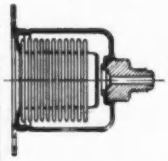
(L) Same as type (C) except with end fittings or heads spun into both open convolutions after forming.



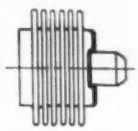
(M) Same as type (B) except that mechanical fittings are attached to both of the end convolutions.



(N) Sub-assembly for rotating shaft seal bellows such as might be used in refrigeration machines.



(O) Conventional bellows and cup assembly.



(P) Bellows with valve pin spot welded to closed end of bellows.

What to Consider When Selecting A

1. CONSTRUCTION

Open ends
Closed ends
Soldered fitting
Mechanical fitting
Special assembly

2. MATERIALS

Brass
Bronze
Monel
Stainless Steel
Others

3. FLEXIBILITY

Diameter
Wall thickness
Number of folds
Length

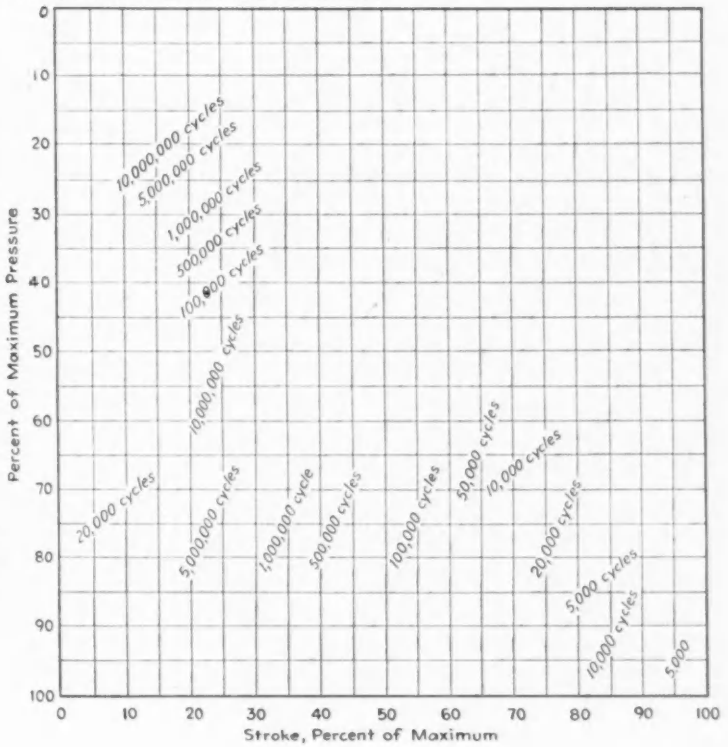
4. FILLING MEDIUM

Gas
Vapor
Liquid

THE BASIC CHARACTERISTIC of a metallic bellows is that it is axially flexible. This flexibility may be great or small, depending on such factors as the material of which the bellows is made, the wall thickness, the ratio of bellows length to diameter, and others. But if properly selected and applied, the bellows can be made to linearly or differentially respond to changes in temperature or pressure. In this respect, it is somewhat similar to a metallic diaphragm.

In so far as control of temperature or pressure is concerned, an electric strain gage might also be used. The difference between such devices and a bellows assembly is largely one of refinement and cost. The strain gage is highly sensitive and can be used under a wider range of operating conditions, but the bellows is less costly and does not require separate control devices or extensive instrumentation. As a matter of fact, most applications do not require any auxiliary actuating equipment, the movement of the bel-

Life Prediction Chart for Metallic Bellows



A. H. ELLIS and J. H. HOWARD
Clifford Manufacturing Company

Metallic Bellows

5. LIFE

- Stroke
- Pressure
- Temperature
- Operating frequency

6. APPLICATION

- Temperature control
- Pressure control
- Shaft seal
- Expansion joint
- Coupling
- Liquid transmission

lows being depended upon to move the controlled device and thus regulate the desired quantity.

CONSTRUCTION OF BELLOWS

A bellows usually is formed in one continuous operation from a thin seamless tube into the finished form, but the final construction may be varied considerably. Both ends may be opened or closed. If open, they may be open on the folds or between the folds. The ends may be fitted with different attachments: An internal or external screw head attachment; a special fitting having a valve pin on the end; a special shaft seal fitting; or an enclosing envelope. These modifications are shown in the accompanying table. The reasons for these various constructions is to facilitate assembly or to improve adaptation of the bellows to a particular control device, as will be discussed.

MATERIALS

Bellows can be made of any one of several metals. Brass, of an 80-20 composition, is by far the most common. Bronze, phosphor bronze (95 copper-5 tin), cupro-nickel alloys, Everdur, nickel, Monel, stainless steel, and silver clad brass also are used. The type of material selected depends primarily on the atmospheric conditions encountered in service, the operating temperature, and on the gas or liquid with which the bellows comes in contact. It does not depend on the amount of expansion or travel required per increment change in pressure, as this usually is taken care of by varying the wall thickness.

FLEXIBILITY

The flexibility of a bellows is directly proportional to number of convolutions in a given length, materials and wall thickness remaining the same. Doubling the number of convolutions doubles the flexibility and halves the spring rate. While this may be done when space is limited, the simpler procedure is to use a longer bellows. However, the length to diameter ratio should not be much greater than 1 to 1 to avoid buckling in service. This tendency can be alleviated to some extent by using an internal or external guide.

The smaller the diameter, the less the flexibility and the smaller the deflection with a given load. Flexibility in terms of stroke per unit load varies directly as the square of the outside diameter of the bellows. The stiffness of a small bellows therefore may require that the length be increased to 1½ or even twice the diameter to obtain the desired length of travel.

FILLING MEDIUM

A bellows may be a thermostatic assembly, in which case it is operated by the fluid with which it is filled. This fluid may be a liquid, gas or vapor.

Bellows that depend on gaseous expansion are filled with an inert gas. Changes in temperature cause corresponding changes in volume. This type of control requires a bulb sub-assembly whose volume is many times greater than that of the bellows. Even with such an arrangement, however, the movement of the bellows per unit change in temperature is small, and the switch or valve to be operated must be capable of functioning with a bellows movement of 0.006 to 0.007 in.

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or less. This class of bellows usually is applied at low temperatures—on the order of 300 F maximum.

Vapor pressure bellows are widely used for temperature control of either heated or refrigerated spaces. To generate the necessary pressure at temperatures below normal and yet keep the pressures at higher temperatures from becoming excessive, the bellows is filled with a minute amount of fluid whose vapor pressure characteristics are suitable for the temperature range in which the bellows assembly is to operate. By controlling the amount of fluid introduced into the bellows, the total pressure generated at a specified temperature can be limited. Such bellows have greater sensitivity and more power than units filled with gas. Also, good regulation is obtained even with a small bulb and a large bellows.

Liquid filled bellows are usually small and compact, can exert a relatively large force, and, while expansion per unit change in temperature is small, they are usually less affected by variations in flexibility than bellows of other types. The change in length per degree F change in temperature is on the order of 0.001 in. maximum. However, smaller changes in length per degree F change in temperature make regulation possible over a range from 100 to 650 F; as a general rule, the expansion of the liquid per degree change in temperature is greater for liquids having a low boiling point.

When used for control purposes, liquid filled bellows are extremely accurate.. They are generally applied for actuation of switches that must operate over a wide temperature range at moderate sensitivity. Many bellows used on aircraft are of the liquid filled type, but for another reason: Their accuracy is only slightly affected by changes in barometric pressure.

There is one other type of bellows, the aneroid bellows, that also is extensively used in aircraft. This is an evacuated unit that is extremely sensitive to changes in atmospheric pressure; as the atmospheric pressure becomes less, the bellows expands. One use is for oxygen-air regulators. Another is to regulate the fuel-air ratio to the engine. While there are some uses other than for aircraft for this type of bellows, they are not extensive.

LIFE

The actual life of a bellows is dependent upon many factors, but for any given bellows is dependent on the operating stroke and pressure. The further the bellows operates away from the maximum stroke and pressure rating for any given frequency of operation, the longer the life rating, as seen on page 87. But affecting this rating are the variables previously discussed, namely material, wall thickness, and number of convolutions.

The heavy lines on the chart are used to determine life if the working pressure is approximately constant throughout the stroke. The vertical scale on the chart deals with pressure, and the horizontal scale with deflection or stroke. For example, if the percentage of maximum stroke is 20 percent, and the percentage of maximum pressure is 55 percent, following both scales in to the point of intersection gives a probable life rating of a little more than 1,000,000 cycles.

On the other hand, if the working pressure is not constant but varies from zero up to the maximum specified figure during each stroke of the bellows, the dotted lines or curves on the chart indicate the life, which in the example just given, works out to be under 100,000 cycles.

APPLICATIONS

Bellows are used primarily as pressure or temperature sensitive devices, or as shaft seals on mechanical equipment, as follows:

1. Temperature control for refrigerators, air conditioning equipment, internal combustion engine thermostats, furnaces, compensating regulators, or process equipment.
2. Pressure control for process equipment, carburetor altimeter controls for aircraft, fuel and manifold pressure gages for aircraft, pressure recording and controlling instruments, oxygen regulators or other compensating regulators, or as pneumatic reversing units on servomechanisms.
3. Seal assemblies for fuel oil pumps, fluid couplings, torque converters, air compressors, gear boxes, and other equipment requiring a positive, yet flexible seal.

The requirements for each of these applications are different, and therefore govern to some extent the type of bellows that can be selected.

SHAFT SEALS. As a shaft seal, the primary advantages of bellows are that (1) being flexible, they compensate for misalignment and (2) being metal, they can withstand high temperatures and pressures.

The sealing of a rotating shaft projecting from a closed system against leakage of gas is shown in Fig. 1. This assembly, which is a refrigeration compressor shaft seal assembly, involves a bellows, flange, and seal nose assembled with a thrust spring.

The design of these assemblies is critical. Flatness of the seal face often must be within two or three light bands; shaft speed, working temperatures and pressures, vibration, and space must be considered; the seal nose itself must be proportioned to have sufficient mass to prevent distortion during manufacture and when in service at elevated temperatures. These details vary for each individual job, however, and recommendations should be obtained from the manufacturer.

Two other examples of sealing applications are illustrated in Figs. 2 and 3. The valve in Fig. 2 is a packless type—the bellows taking the place of the packing. Flatness tolerances are relatively unimportant in this application, since both ends of the bellows are soldered to a brass assembly.

The application in Fig. 3 is somewhat more unique. Made by the Kearfott Co., Inc., this device is designed to transmit rotary motion through a positive metal to metal seal, and consequently is used to obtain internal adjustments in hermetically sealed instruments and electrical and electronic equipment. Since the bellows is flexible, it is attached between the oscillating shaft and bearing and thus provides a positive seal.

TEMPERATURE CONTROL. A bellows used for the regulation of temperature is usually, but not always connected with a flexible capillary tube that is extended into the chamber or fluid to be regulated; the tubing may or may not be connected with a bulb. The bellows assembly is charged with a thermosensitive gas or liquid. Variations in the temperature of the regulated medium effect changes in the contained gas or liquid, which are transmitted to the bellows. Linear movement of the bellows actuates an electric or mechanical control device, such as an electric switch or a suitable valve.

Requirements of the bellows are that it be strong enough to withstand the internal pressure created by a rise in temperature and the external resistance of the switch or controlling mechanism; and that it be filled with vapor or liquid correctly selected for the temperature-thrust range involved.

In refrigerator applications, the bellows is used with a bulb assembly, Fig. 4. It increases in length as the bulb is heated, closes electrical contacts, and starts the compressor motor. As the temperature decreases, the bellows contracts and breaks the circuit. A spring adjusted electrical contact usually is used, the bellows being of the limited fill type having a methyl chloride charge.

When applied to control the heating element in an electric range, Fig.

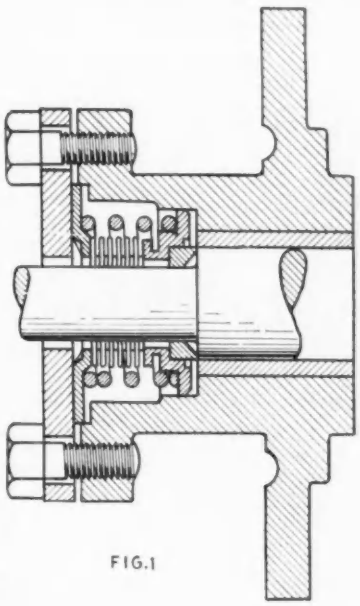

FIG.1

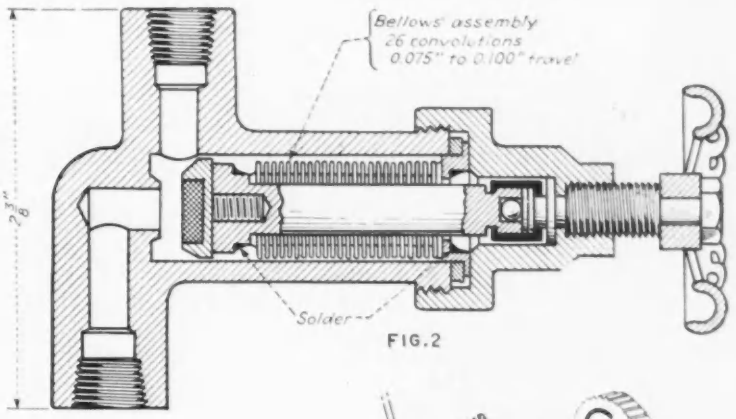

FIG.2

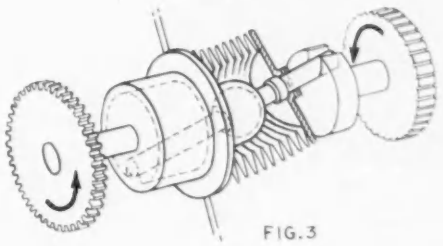

FIG.3

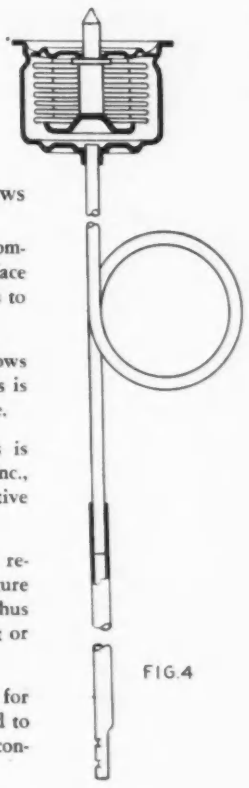

FIG.4

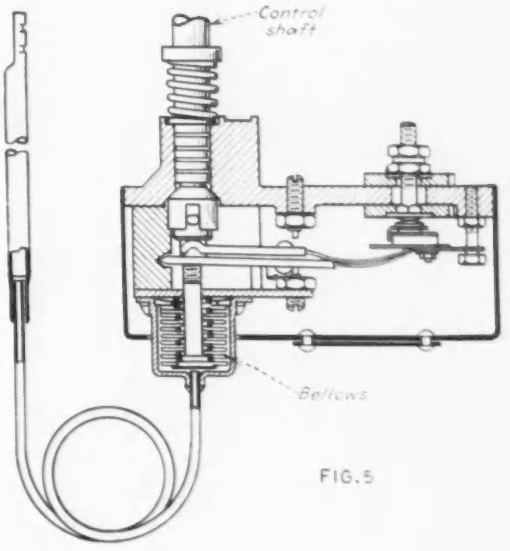

FIG.5

Typical Applications of Metallic Bellows

Fig. 1—Bellows shaft seal for refrigerator compressor shaft. Flatness of the flange surface often must be within two to three light bands to insure a tight seal.

Fig. 2—Packless valve having a metallic bellows as the sealing unit. Advantage of the bellows is its high pressure and temperature resistance.

Fig. 3—The lateral flexibility of a bellows is utilized in this device, designed by Kearfott, Inc., which transmits rotary motion through a positive metal to metal seal.

Fig. 4—"Limited fill" bellows assembly for refrigeration application; changes in temperature cause the bellows to expand or contract, thus opening or closing a precision switch to start or stop the compressor motor.

Fig. 5—Thermal liquid expansion bellows for electric oven control. Spring pressure is used to regulate bellows movement, which in turn controls the on and off switch.

5, the bellows expands and opens the contact above a certain temperature; when used in a gas range, expansion of the bellows acuates a control valve and throttles down the gas flow. The bellows is filled with a chemically stable liquid for operation up to 650 F.

When used as an overload protective device for electric motors, the supply lines to the motor may be wrapped around the bulb or else the bellows may be put directly in the motor circuit. A bulb also could be placed in the motor winding. Over loads heat up the bellows, which then expands and breaks supply contacts.

PRESSURE CONTROL. Since even those bellows that are used for temperature control are actuated by pressure, it is a simple matter to apply the units directly in pressure indicating and recording instruments or control devices. The hook-up is similar to those already shown except that one end of the bellows usually is equipped with a fitting for the pressure supply line. This is not always necessary if barometric pressure is relied on to actuate the bellows as is the case with evacuated bellows used in aircraft.

In both pressure and temperature applications, two or more bellows can be directly connected together, or connected through suitable levers, so that motion of one affects the motion of the other. The motion relationship is dependent on the method of connection and on flexibility and size of the units. Thus the type of application governs not only the type of bellows, but its physical construction as well.

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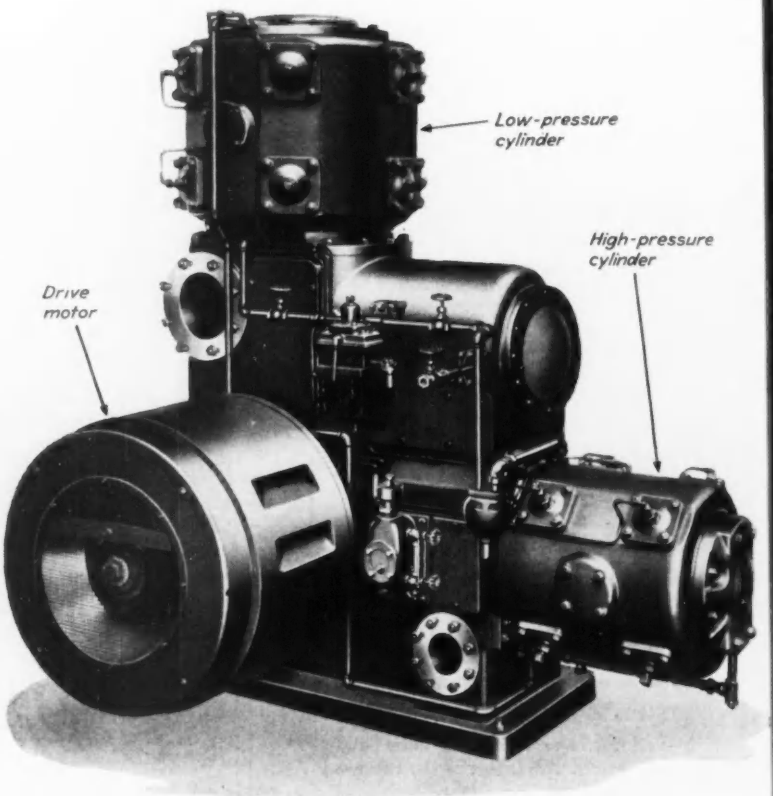
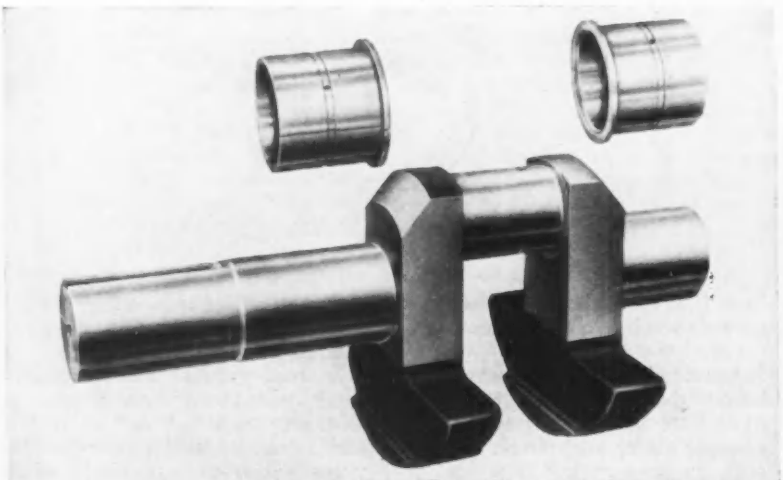
Integral Ducts Replace Piping In Compressor

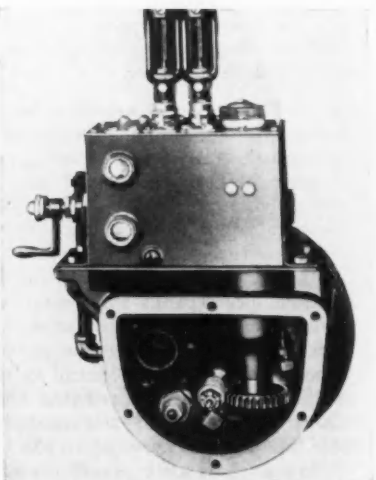
A new L-type cylinder arrangement is the feature of a new line of air compressors made by the Ingersoll-Rand Company of New York City. Sizes of the electrically driven machines range from 125 to 350 hp. Compactness is achieved by the use of a vertical low pressure cylinder and a horizontal high pressure cylinder with the synchronous drive motor connected directly to the crankshaft. The L design requires less floor space and makes for improved balance of reciprocating forces. The compressor frame includes integral ducts for air flow. There is no piping within the compressor. The intercooler is of tube and fin design and is installed as a package unit.



LARGEST OF THE NEW two-stage compressors is driven by a 350 hp synchronous motor. The piston displacement of this model is 2397 cfm generating output pressures from 80 to 125 psi. Because of the L cylinder arrangement, new models require less floor space than V-type machines.

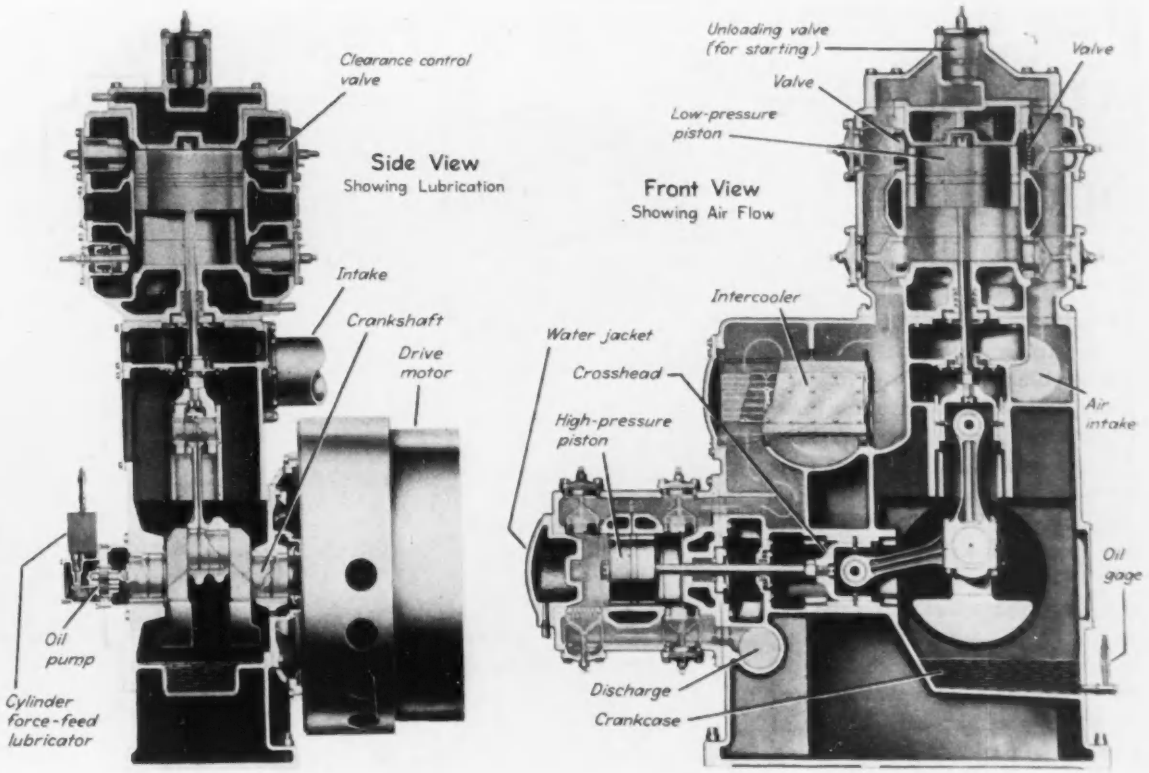


CRANKSHAFT is designed to carry the rotor of the drive motor. All bearings are free to rotate within the bearing housing. Thus, shaft speed is reduced in relation to the bearing. Wear is distributed evenly around the entire bearing surface, both inside and out, and is not concentrated at any one point. Both the main and crankpin bearings are pressure-lubricated.

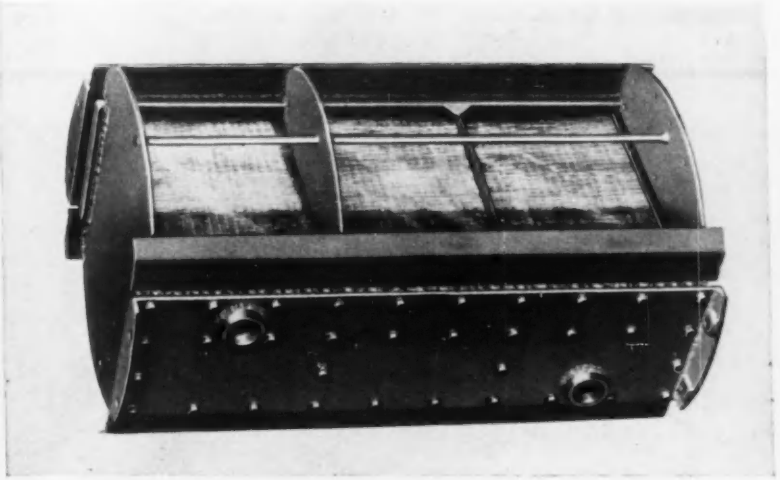


GEAR OIL PUMP for running gear lubrication is driven from end of crankshaft. Vertical shaft that drives the cylinder lubricator is worm-geared directly to the pump shaft.

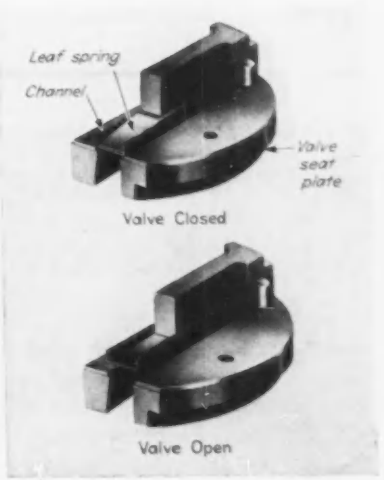
D E S I G N S



INTAKE AND DISCHARGE CONNECTIONS are on the compressor frame instead of on the cylinders. Internal air flow is through passages within the frame. This eliminates all interstage piping and reduces the length and height of the compressor. Since cylinders support no piping, the possibility of straining the cylinder flange connections is removed. All bearing surfaces are pressure lubricated through drilled passages to eliminate piping.



PACKAGED INTERCOOLER fits within compressor frame. This finned tube unit needs only ¼ the space required by the common-tube-nest type coolers. Copper tubes are brazed onto bronze headers, and the copper fins are sweated on the tubes. Water condensed from air passing through intercooler is automatically ejected from compressor frame. The component is compact and lightweight.



CUTAWAY valve section shows operation. Valve allows air to pass through freely in one direction, but closes automatically when air flow is reversed. Parts are stainless steel.

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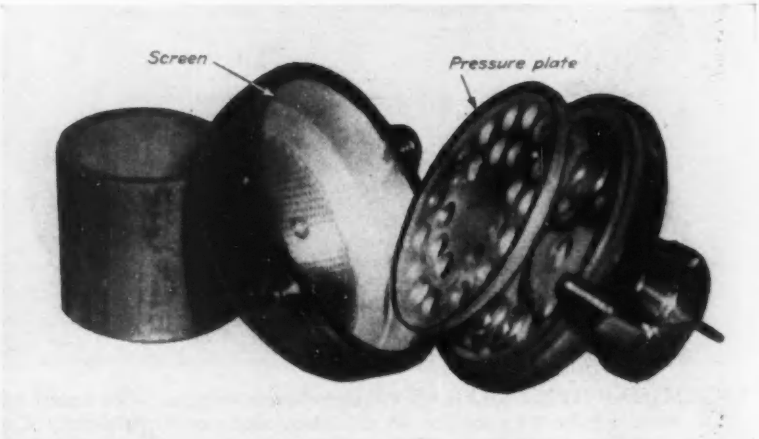
Fiat Car Has Multiple Rear Springing

Mechanical features of the redesigned Italian-built Fiat automobile are a unitized body and frame; a short stroke-wide bore four cylinder engine and a new rear suspension. The latter is a combination of three types of springing—coil, leaf and torsion bar. The coil springs carry the main loads so that the rear end ride is basically soft. Two half-section leaf springs also act on the rear axle. These share the springing, serve as radius arms which hold the axle in position and replace the conventional stabilizer bar. The third element is a cranked compensating rod or torsion bar that provides a progressive stiffening of the suspension as the axle approaches the limit of its travel during bump or rebound. The effect of this is to lessen the possibility of the axle grounding against the frame when the car is subjected to violent shocks.

CONSTRUCTION is integral body-frame type. One advantage of this is facilitated servicing. All mechanical units can be removed without disturbing the coachwork by loosening 18 bolts. Wheelbase of the car is 104 in. and road weight is 2,550 pounds. The four cylinder engine delivers 45 hp at 4400 rpm. Cylinders are equipped with liners that can be removed and replaced when the automobile requires a major overhaul.

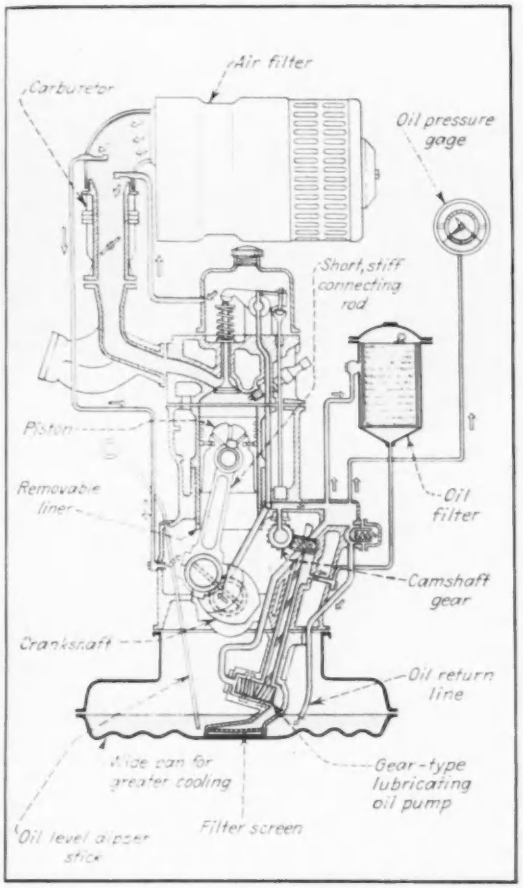
Fast Welding Stops Rejects

A change in the assembly method simplified production of this household water filter. The Sparkler Mfg. Co. of Mundelein, Ill., now uses argon-shielded arc welding in place of silver brazing. Because of the rapidity of the weld, there is no danger of drawing the temper of the springs or of warping or discoloring the plate, as with former methods.

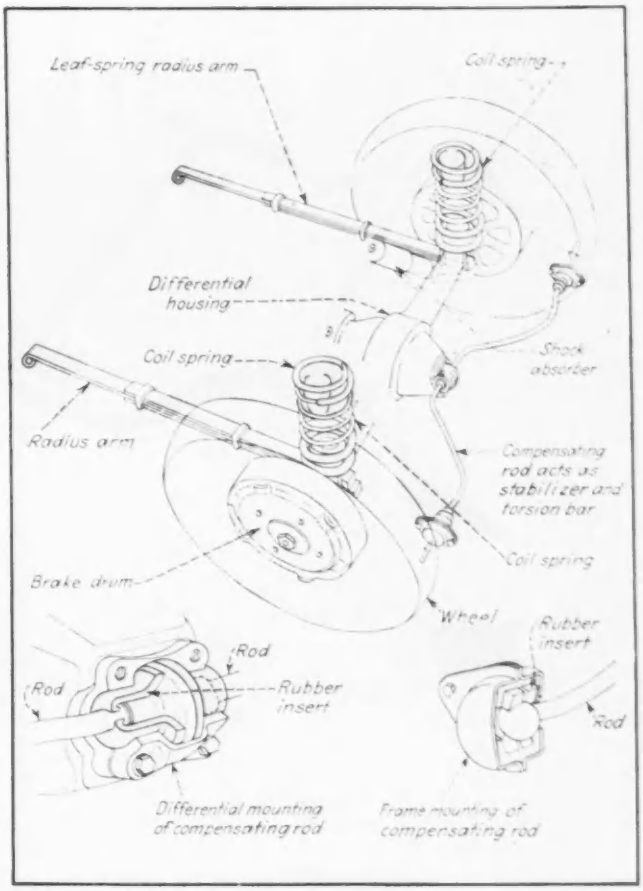


The Linde Air Products Company

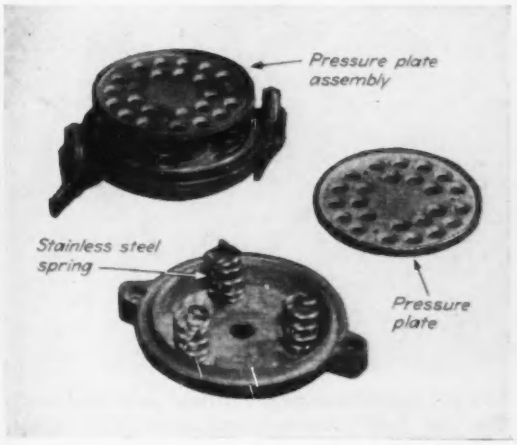
PRESSURE PLATE is used to hold a replaceable filter unit against a stainless steel screen. The pressure plate is made of nickel plated bronze.



ENGINE is "flat" type in which cylinder bore is greater than the stroke. This makes possible use of short, rigid connecting rods, which reduce vibration. Also, the shorter piston travel means a reduction in friction losses. Volumetric efficiency is greater because of the large diameter valves used.



COIL SPRINGS are main elements of rear suspension but the axle is located by leaf spring radius arms. Any tendency to roll produces a combination of deflection and twisting in the leaf springs. Thus, leaf springs have a stabilizing effect. Inset sketches show rubber mounting of the cranked compensating rod which resists lateral axle movement.



IN ASSEMBLY, three stainless steel springs are welded. Prolonged welding might warp plate.

WELDING TIME has been reduced to 2 or 3 sec per weld. No flux is used. Previously, plate required cleaning.

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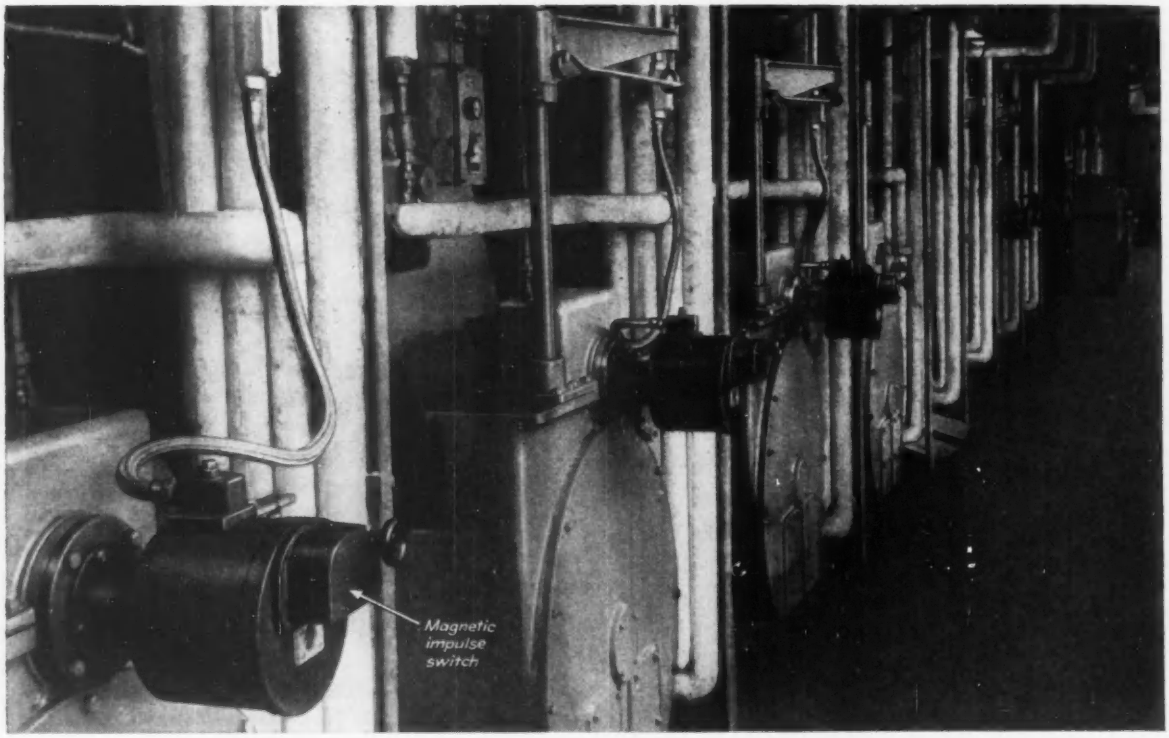
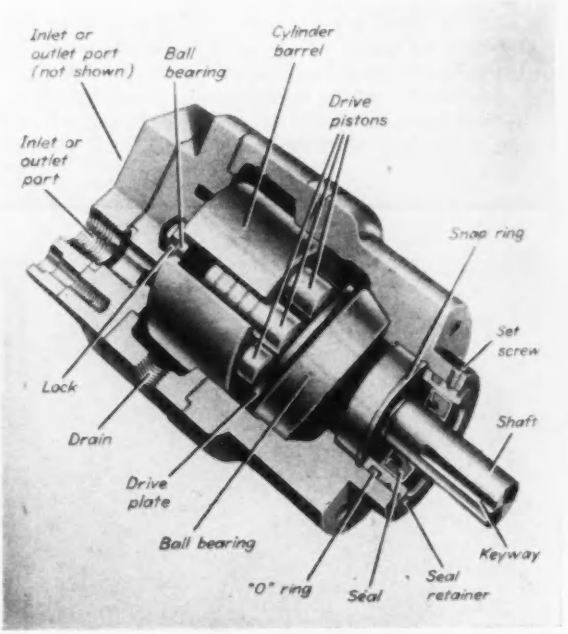


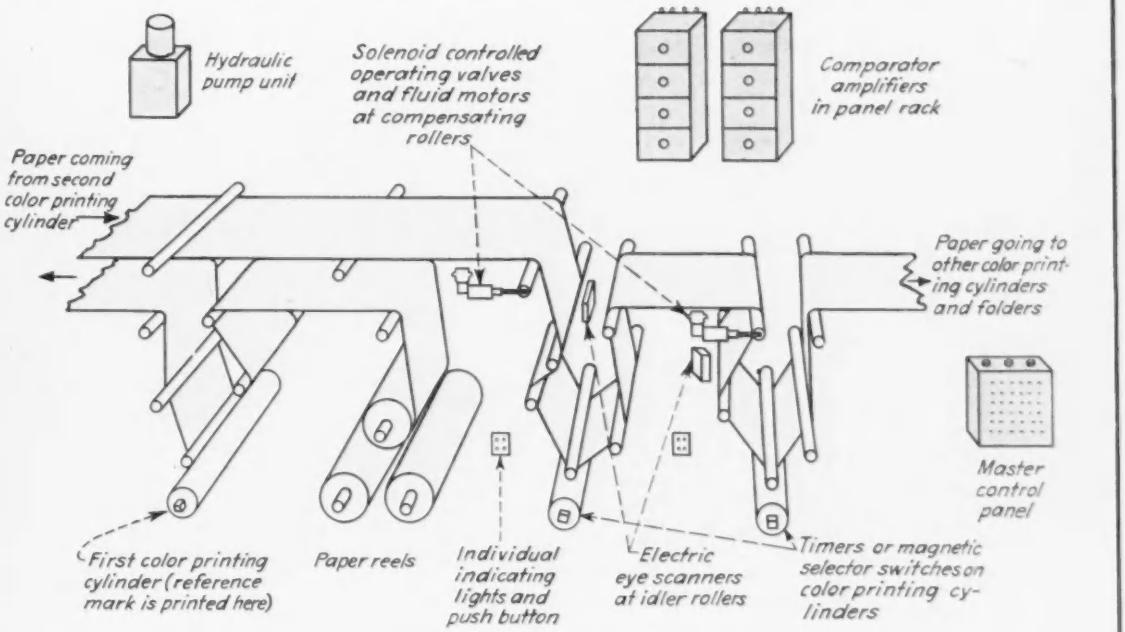
MAGNETIC IMPULSE SWITCHES are mounted on the shafts of the color printing cylinders. The above picture is a view along the drive side of a large, multi-cylinder press. Printed colors are in perfect register when the electrical impulses from these switches reach the comparator amplifiers at the same instant as impulses from the electric eye scanners. The latter are actuated by reference marks on the rapidly moving paper.

Control System for Color Printing Press

The "Hurletron Registration Control" automatically maintains precise coordination of colors in high speed, multi-cylinder printing presses. Developed by the Electric Eye Equipment Co. of Danville, Illinois, the system detects errors in color register electrically and corrects them instantaneously by means of hydraulic apparatus. The first color cylinder prints a reference mark on the paper. Before the paper reaches the next cylinder, it is scanned by a photoelectric cell. Each time this cell "sees" a reference mark it transmits a signal to an electronic amplifier. This signal is compared with an impulse from a switch that is mounted on the second color cylinder. If both signals are not in phase, the hydraulic system takes corrective action. The hydraulic pumping unit, solenoid controlled operating valves, and fluid motors are products of the Denison Engineering Company of Columbus, Ohio.

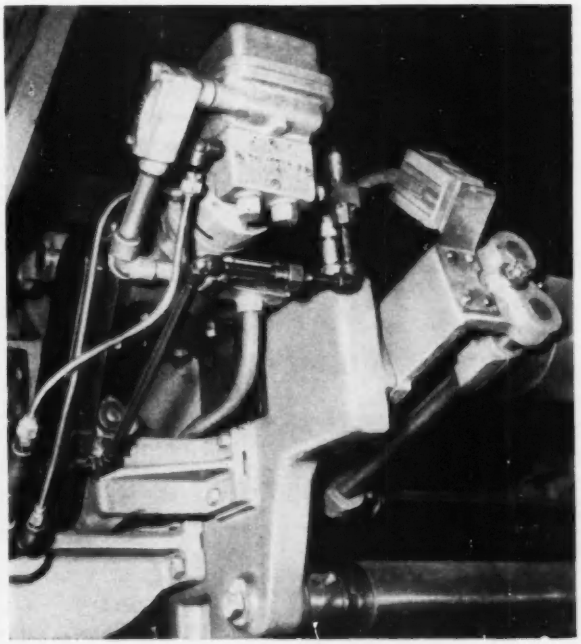


NORMALLY, equal pressures entering both inlet ports immobilize the fluid compensating motor. When colors are out of register, a solenoid valve closes off one or the other of the inlet ports to produce the required direction of rotation.

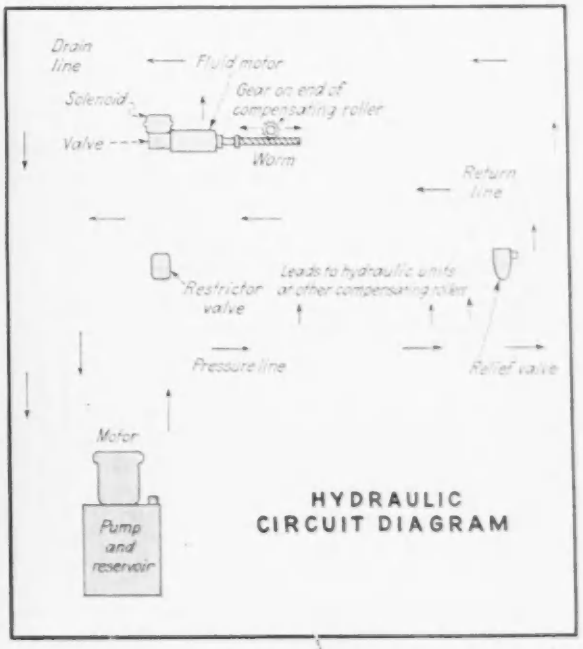

Hydraulic pump unit
Solenoid controlled operating valves and fluid motors at compensating rollers
Comparator amplifiers in panel rack
Paper coming from second color printing cylinder
Paper going to other color printing cylinders and folders
Master control panel
First color printing cylinder (reference mark is printed here)
Paper reels
Individual indicating lights and push button
Electric eye scanners at idler rollers
Timers or magnetic selector switches on color printing cylinders

PARTIAL SCHEMATIC DIAGRAM OF MULTI-COLOR PRINTING PRESS

WHEN COLORS are not coordinated, the comparator amplifier energizes the solenoid valve that controls operation of a fluid motor. A worm connected to the motor shaft shifts the compensating roller back or forth along a horizontal plane. This action has the effect of lengthening or shortening the distance the paper must travel between color cylinders. Thus, color coordination is maintained despite angular misalignment of printing rolls.



HYDRAULIC ASSEMBLY is connected to the compensating roller. The assembly consists of a fluid motor and solenoid-controlled operating valves. These valves are mounted directly on the motor shell. This eliminates excessive piping and assures a compact assembly.



HYDRAULIC CIRCUIT DIAGRAM

PRESENCE OF EXPLOSIVE INK VAPORS in the pressroom influenced designer's choice of hydraulic actuation. Pump-reservoir unit is located outside the pressroom. Restrictor valves limit the speed of the motors by controlling fluid flow through the hydraulic lines of the system.

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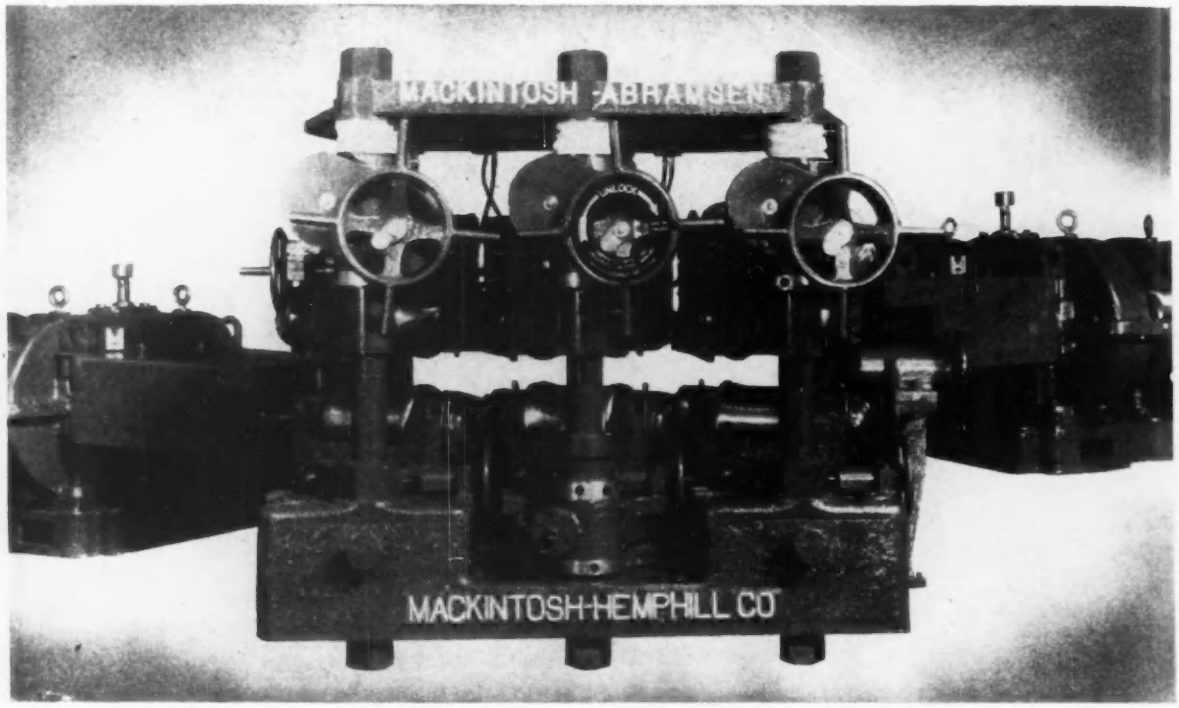
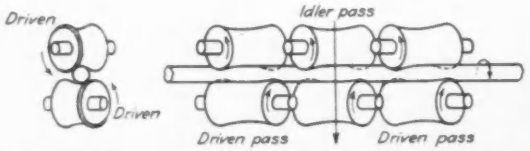


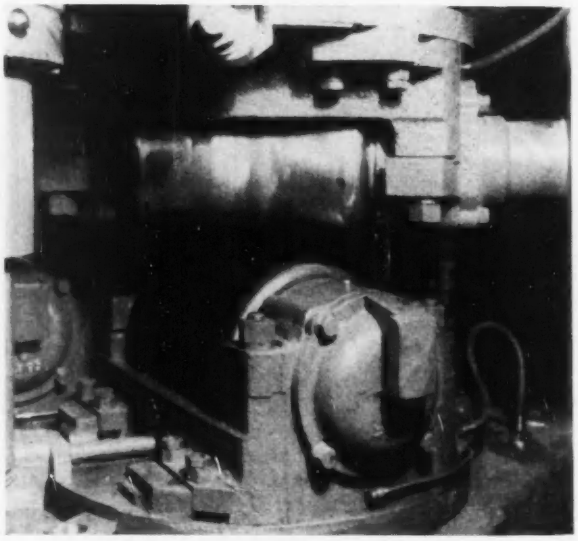
TWO 25 HP D-C MOTORS drive the tube straightening machine. Motor speeds are electrically and mechanically synchronized. A single rheostat controls both motors, each of which is equipped with a vernier rheostat to compensate for any difference in their speed characteristics. Motors are mechanically interlocked by having one motor drive top rolls and the other operate bottom rolls. The stock, in passing between rolls, tends to hold motors at same speed.

Cross Roll Straightening Machine

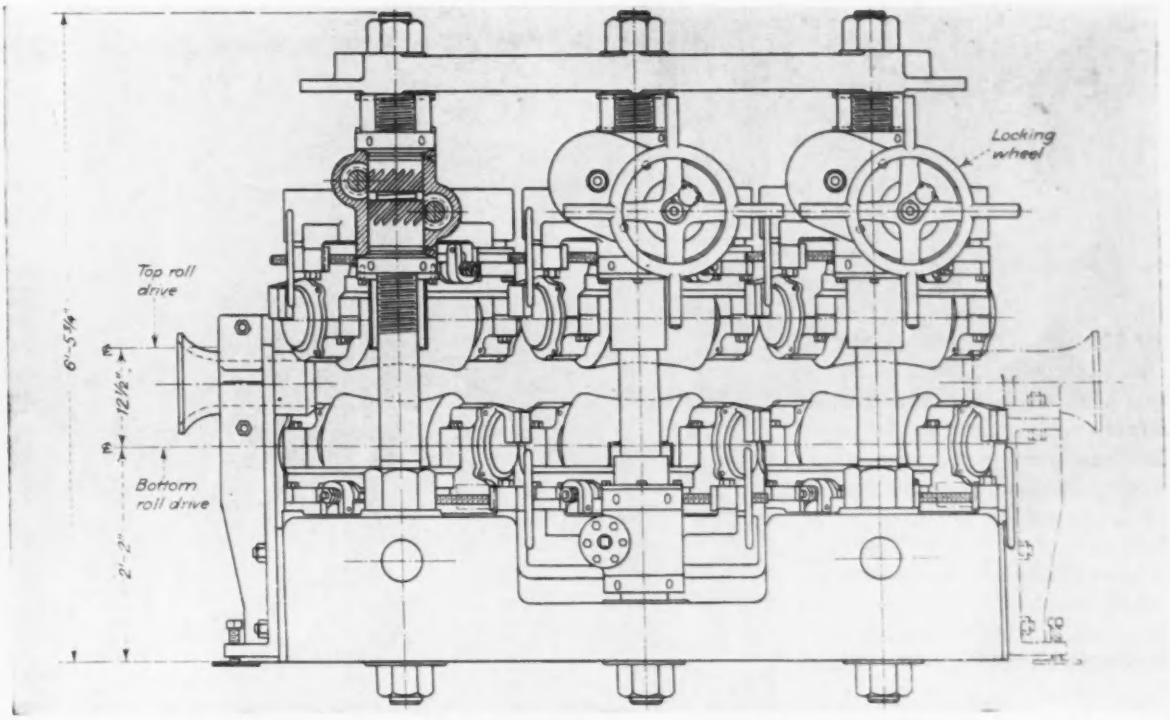
This machine removes bends and kinks from 2 in. rounds at the rate of 7,000 twenty-foot pieces per 8 hr day. Since rolls do the straightening, power consumption is about 50 percent less than for machines having rigid guides. Mackintosh-Hemphill Co., Pittsburgh.



STRAIGHTENING IS ACCOMPLISHED by offsetting the cross roll idler pass which is located between 2 fixed cross roll passes. The stock does not slide over stationary guides. Hence, no power is dissipated in guide friction. The entire surface of each roll takes part in the straightening action.

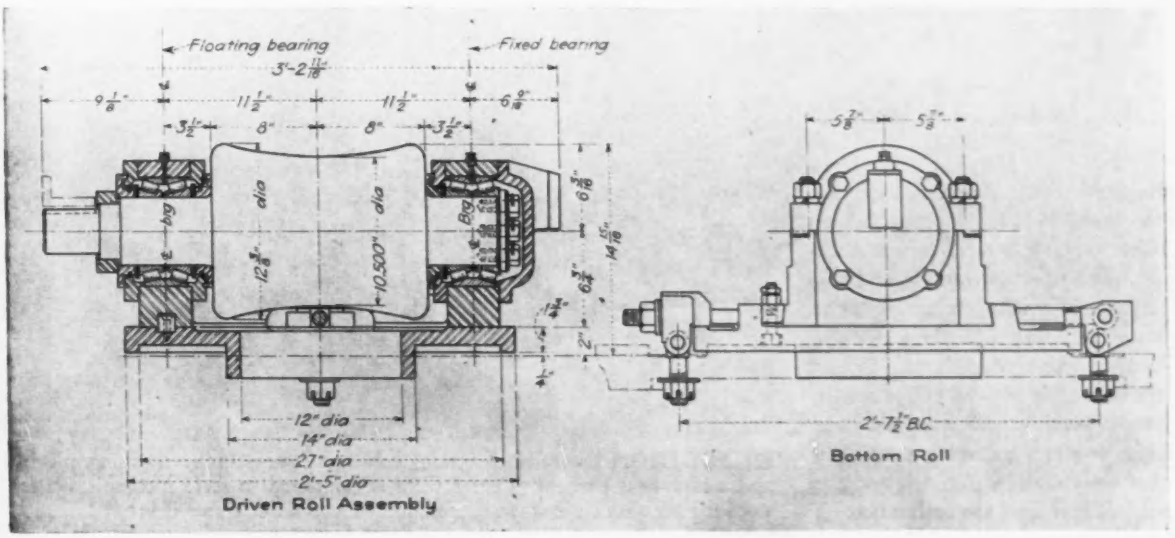


CRADLE-TYPE ROLL BEARINGS simplifies the task of changing rolls. The bearing housing is of one-piece design. A rotatable plate carries the roll assembly. The housing is fixed within an angularly machined slot by a vertical gib. This gib takes up the clearance between housing and plate. Removal of gib frees entire roll assembly.



MACHINE IS SET UP for various diameters of stock by adjusting the angular position of the rolls and the clearance between them. The adjustments are made by worms or nuts operated by conveniently located handwheels. Indicators make possible duplication of any setting of the machine. The bottom rolls remain at the same elevation for every size of bar or pipe. Hence no vertical adjustments to the entering or leaving equipment are required after changeover from one size to another. Open sides make parts accessible for repairs or adjustments. The posts are of rolled steel, threaded for the bronze adjusting nuts mounted in the roll carrier.

ROLLS ARE CARRIED on tapered, double-row roller bearings, which are completely enclosed in oil tight housings. Lubrication of all roll neck bearings is through a centralized lubrication system, powered by a hand operated pump. The complete roller assembly—including bearings and housings—is quickly removable as a unit. Rolls are castings of iron alloy, the exact composition of which depends on the service specified. The axis of the bar or pipe passes through the intersection of the center lines of the cross rolls. This assures uniform wear on the surfaces of the rolls.



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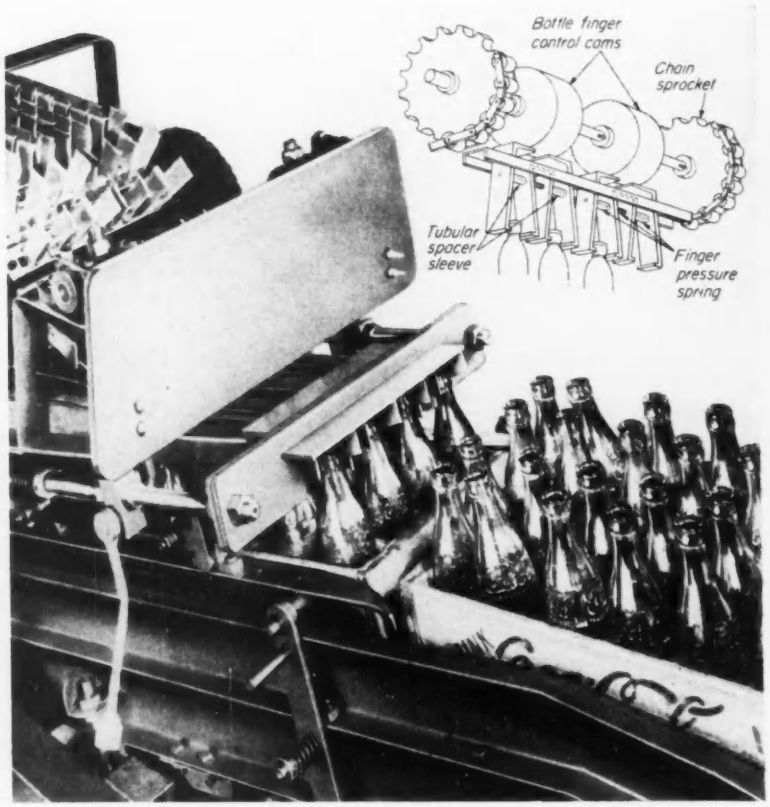
High-Speed Bottle Uncaser

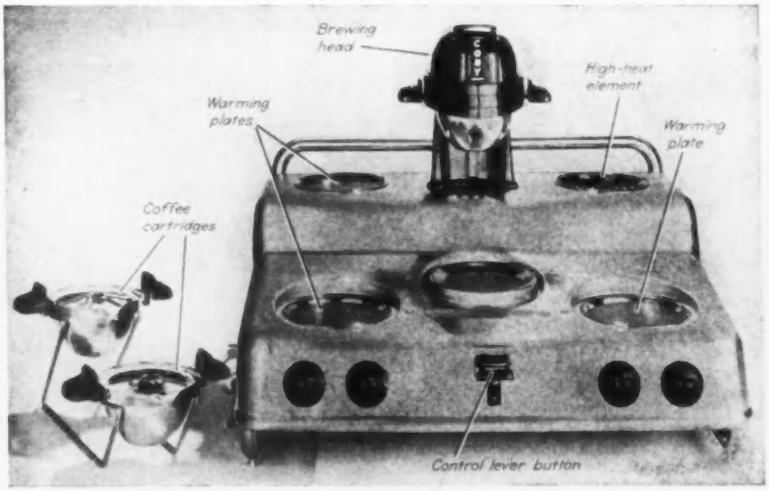
The Uncaser and Washer-Loader is a late addition to RCA's line of bottling plant machinery. It automatically removes empty bottles from their cases and feeds them to a washing machine at speeds up to 500 bottles per minute. Simplicity is the keynote of the design. The separation of bottles and cases is accomplished entirely by conveyor arrangement. All motions are smooth and uni-directional. The absence of abrupt reciprocating movements and the associated problems of control and timing contributes to the uncomplicated design and makes possible the high speed operation. Also, direct cam action was chosen to actuate the bottle holding fingers. Atkron, Inc., of Cuyahoga Falls, Ohio, manufactures this equipment for the Radio Corporation of America.



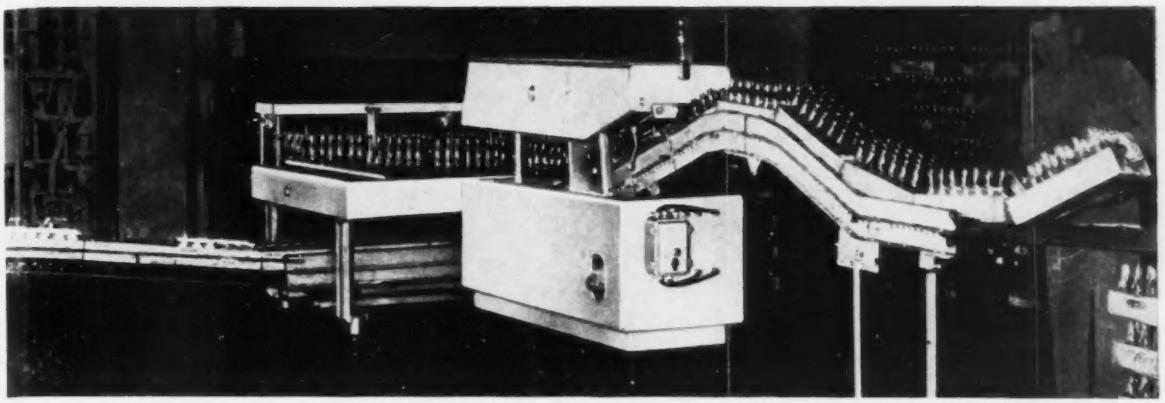
GUIDE RAILS and channels accurately center the incoming cases and align the bottles with the holding fingers. Automatic safety switches stop the machine if a bottle is in a position that would prevent its passage through the infeed gate. The inset shows the simple cam action that controls the opening and closing of the spring loaded fingers. Two cams are mounted on the sprocket shafts at both ends of the loops of roller chain.

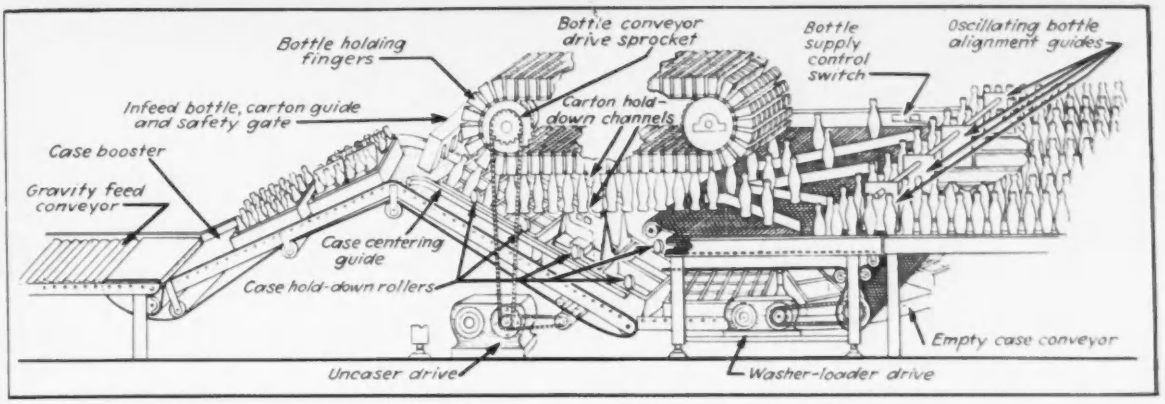
Automatic Coffee Maker

Designed for commercial service, this new Cory development makes coffee brewing a push button function. The operator merely inserts a cartridge of ground coffee, places an empty decanter under the spout and depresses the control lever. Twelve cups of freshly brewed coffee are delivered within three minutes. The device provides automatic control of water quantity, water temperature and infusion time for each batch.

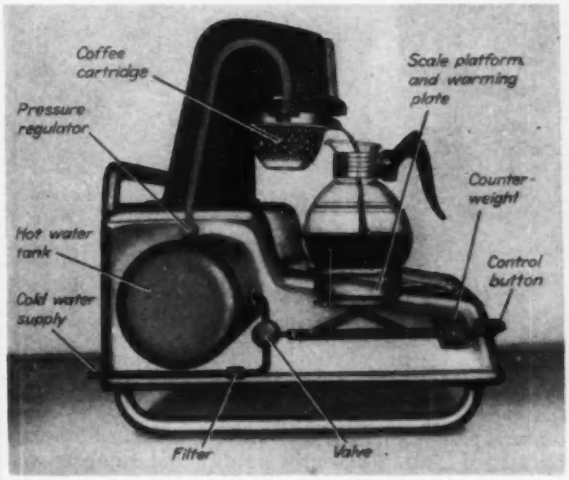


IN ADDITION to brewing section, unit has three standby warming plates and a high-heat element. Center plate is connected to scale mechanism that stops the brewing cycle when predetermined amount of coffee is brewed.

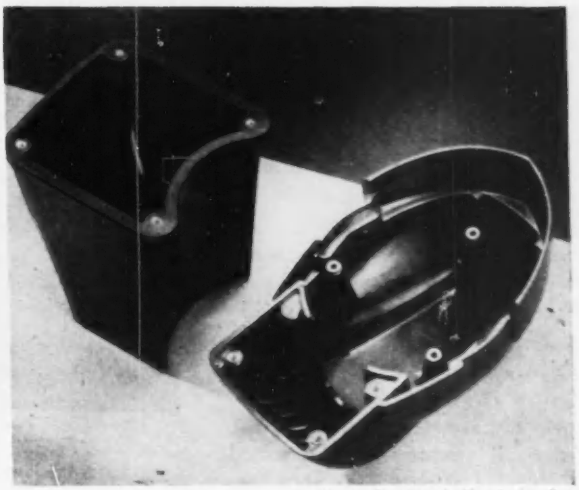




COMPLETE MACHINE comprises two sections. The first section uncases the bottles while the second section carries them into a washer. Cases containing empty bottles are carried to the uncasing machine by means of a gravity feed auxiliary conveyor and booster. As each case moves down an incline, fingers grip the necks of the bottles. The fingers are mounted in rows on an endless belt that moves forward horizontally at the same speed as the case. The widening angle separates the bottles from the case as they are transported to the washer loader conveyor table. Machine speed is varied over wide limits by changing chain sprockets and by adjusting the Reeves Drive setting.



WHEN SCALE MECHANISM TRIPS, it closes the water valve and turns on scale platform warming element. Pressure regulator keeps duration of brewing time constant.



Durez Plastics & Chemicals, Inc.

Original design called for metal brewing head. The change to phenolic plastic eliminated machining and finishing operations and reduced weight more than 50 percent.

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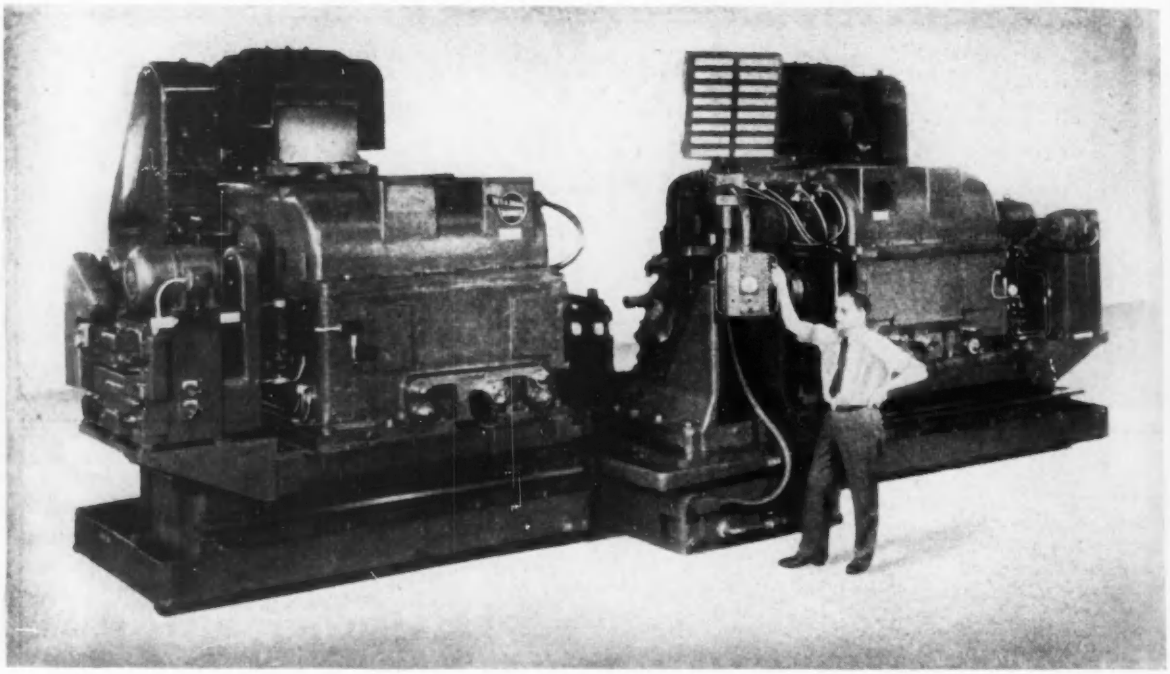
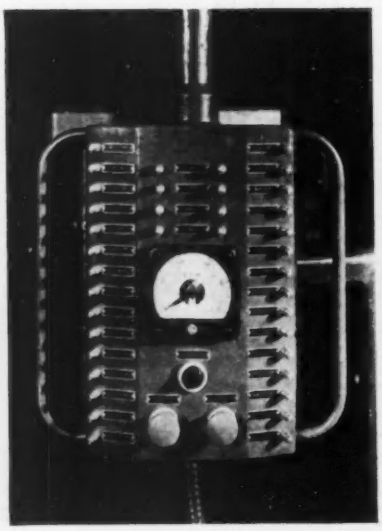


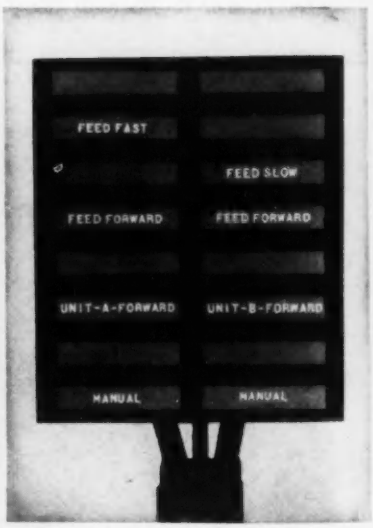
FOUR-SPINDLE, DOUBLE-END MACHINE bores the frame castings for the traction motors of diesel-electric locomotives. The base is of 3-piece construction, bolted and doweled together and measuring 29 x 10 ft. Each of the two machine heads is mounted on two ways, 10 in. wide and 20 in. apart. A roller curtain prevents chips and dirt from injuring the surface of the ways. Precise vertical alignment of the spindles in the two heads is obtained by a matching taper of $\frac{3}{16}$ in. per ft between one head and its saddle. Moving this head horizontally raises it also.

50 Hp Motors Drive Boring Machine

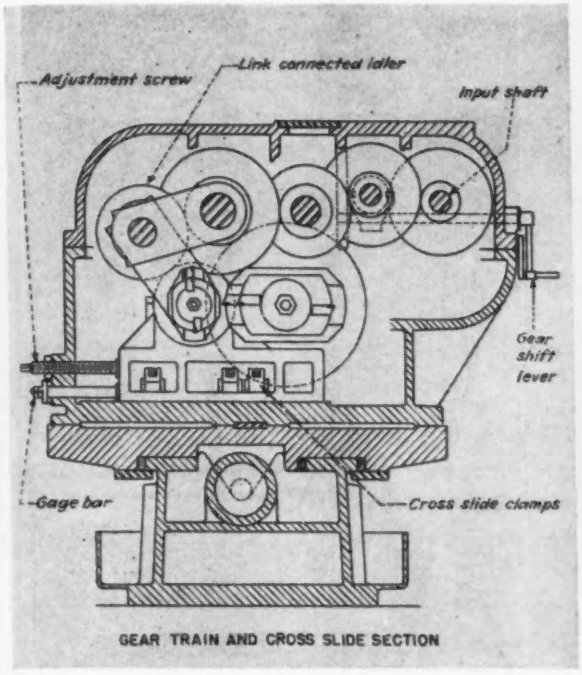
This boring machine was developed by the W. F. and John Barnes Company for use in the manufacture of diesel-electric locomotive traction motors. In one operation, the machine finishes the bores for the motor armature and the locomotive axle. Feature of the design is the hydraulically operated rack and pinion mechanism for aligning the spindles. The machine comprises two opposed boring heads, each powered by a 50 hp variable speed (450/1800 rpm) d-c motor. Speed changes are accomplished by motor driven rheostats and gear shifts. The force-feed lubrication system is equipped with pressure switches that prevent machine operation if improperly lubricated. General Electric's Erie plant has The General Electric Company has the machine on the production floor at its Erie, Pa., plant.



CONTROL PENDANT contains pushbuttons in circuit with motorized rheostats that determine speed of spindle motors. By means of selector switch, speeds of these motors can be read from a single tachometer.

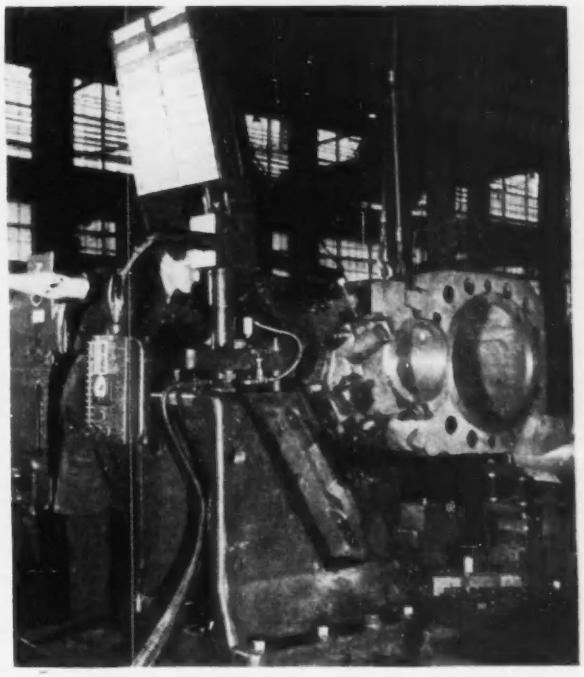


LIGHTED PANEL, mounted directly above the pendant and swinging with it, indicates which phase of the cycle is in operation. Lettered plates are arranged in two rows—one for each end of the machine.



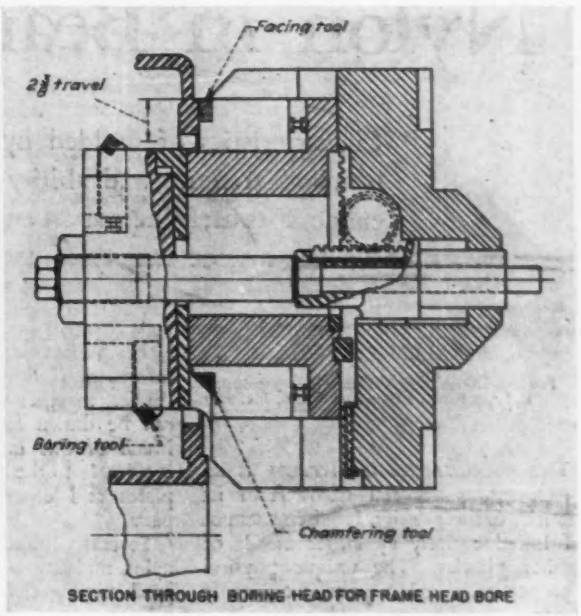
GEAR TRAIN AND CROSS SLIDE SECTION

A 50 HP D-C MOTOR in each head drives both spindles through herringbone gears, some with an 8 in. face. Link-type idler gear permits varying the spacing between the small and large spindles. Adjustment is made by shifting cross slide on which small spindle is mounted.



OPERATOR'S STATION is located at the midpoint of the machine. For machining, the magnet frame casting is bolted down and the heads advance into it from both sides. Feed of cutting heads into the work is hydraulically actuated. The setting of a valve controls feed rate.

MACHINE CUTS AXLE BORES up to 10.750 in. in diameter and framehead bores up to 27 in. in diameter. Spindles are large and carried on roller bearings to attain rigidity and permit the speed range required. With gear shift, speed can be varied from 6 to 160 rpm and 3 to 80 rpm respectively, on the small and large spindles.



SECTION THROUGH BORING HEAD FOR FRAME HEAD BORE

TOOL HEADS CARRY A CROSS SLIDE with tapered take-up gibs. These slides are actuated by a hydraulic cylinder operating a push rod through the center of the spindles. The push rod carries a rack in mesh with a pinion that in turn engages a second rack. The second rack is attached to the cross slide.

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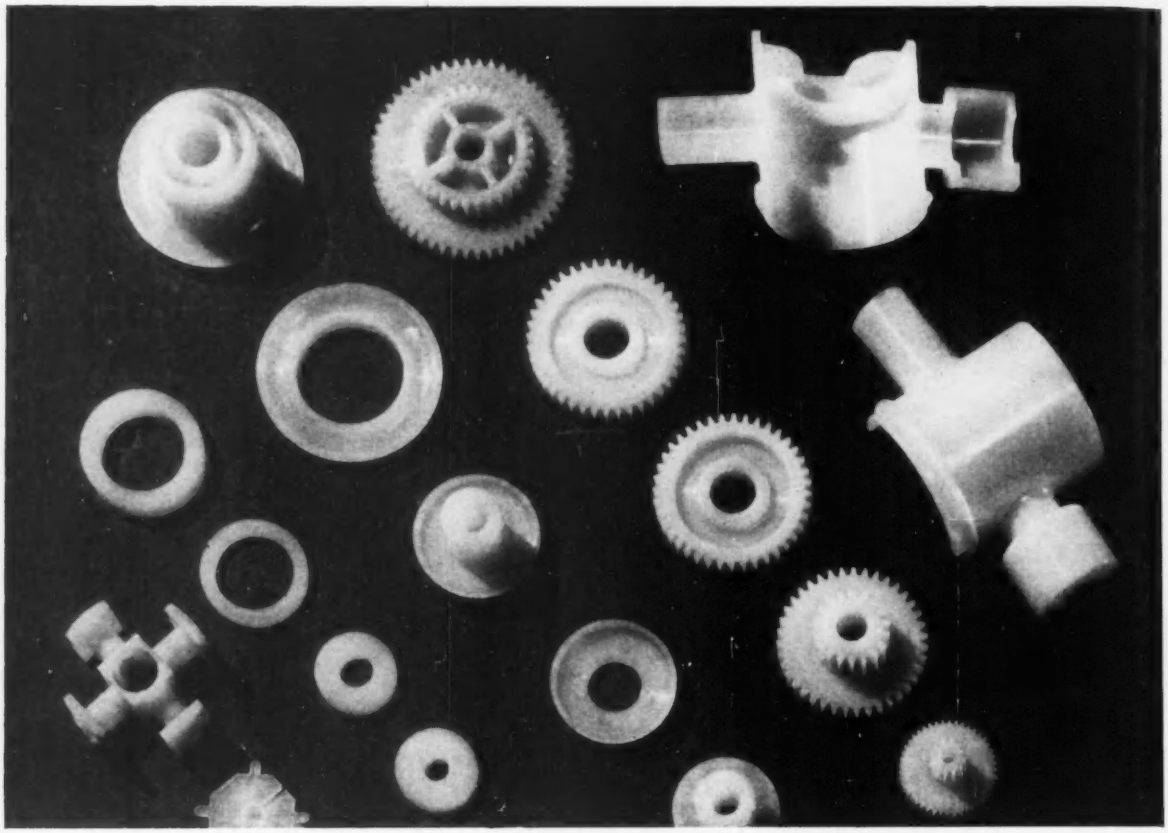

Nylon in Bearings and Gears

Characteristics of molded nylon, including shock resistance, bearing strength, and ability to operate without lubrication, enhance its usefulness as an engineering material. Case histories indicate a wide variety of applications in gears and bearings.

WILLIAM C. WALL

Product Engineer, Polychemicals Department
E. I. du Pont de Nemours & Co., Inc.

THE IMPORTANCE OF NYLON as an engineering material stems from its ability to meet design requirements not fulfilled entirely by either metals or other plastics. The unique physical properties of nylon make it especially useful for bearings and gears, in a wide variety of industrial applications. As a result of the success of nylon in this type of application, a program of study has been initiated to investigate the factors affecting the performance of nylon in bearings and gears. This article will present some of the initial information developed from these studies, together with conclusions that can be drawn from field experience. Much of this information is equally applicable to the design of cams, wear plates and other similar mechanical parts.

Several different formulations of nylon molding powder are in current production, each having specific physical characteristics and adapted to specific fields of application. The nylon most commonly used for mechanical applications such as bearings, gears and cams is type FM-10001. This type has the highest tensile and compressive strengths, is the most rigid, has the best heat-resistance and abrasion-resistance, and is the least expensive of the standard formulations. A description of characteristics and typical uses was given in the article "Molded and Machined Nylon" by Louis L. Stott, in PRODUCT ENGINEERING, p. 103, December 1946. Table I gives the most recent property data for FM-10001 molded nylon; additional property data can be obtained from the du Pont Company, Polychemicals Department, Wilmington, Delaware.

Desired shapes are produced from this FM-10001 nylon molding powder by injection molding, which produces intricate shapes to close dimensions rapidly, and also inexpensively if the

quantity of pieces is sufficient to warrant the die cost. Where the quantity of pieces required is small, machining techniques, similar to those employed for producing like shapes in metals, can be used. Molded or extruded rods, bars and flats of nylon can be obtained for this purpose, in standard dimensions, from molders specializing in these stock shapes. Standard machine tools can be used, at production rates that are usually considerably higher than for yellow brass. Extensive tests have indicated little, if any, difference in the performance of fabricated and molded parts.

Properties

MECHANICAL STRENGTH. FM-10001 nylon has good tensile strength (10,900 psi at 77 F), good shear strength (9,600 psi) and excellent flexural strength (14,600 psi at 77 F).

THERMAL RESISTANCE. Nylon has considerably better heat resistance than any other thermoplastic material, and will withstand continued exposure to temperatures tolerated by many of the thermosetting plastics. FM-10001 nylon has a melting temperature of 507 F, and a heat-distortion temperature, under 66 psi loading, of 405 F. Nylon bearings have been known to perform satisfactorily at surface temperatures above 300 F where lubrication was adequate. Nylon is, however, more sensitive to dry heat than to moist heat. Continuous exposure to dry heat in excess of 250 F may cause embrittlement of the material.

CHEMICAL RESISTANCE. Type FM-10001 nylon is insoluble in common organic solvents, and inert to alkalies. Dilute mineral acids and most organic acids can often be tolerated, even though the resistance to acids is not outstanding. Petroleum oils and greases do not affect nylon to temperatures as high as 325 F, nor are oils and greases affected by nylon, as demonstrated by the Underwood test of SAE. Food acids, lactic acid in milk, photographic solutions, and the like, have little or no effect on nylon moldings. The chemical inertness of nylon permits its use in direct contact with a wide variety of chemical solutions, and this often contributes to simplicity of machine design by avoiding the necessity for fluid seals. Frequently the fluid being handled can be allowed to enter the bearing to serve as an effective lubricant and coolant.

ABRASION RESISTANCE. The abrasion-resistance of nylon is outstanding among unfilled plastics. Nylon yields slightly at the surface but shows little wear over extended periods of service in thermally stable installations. Its load-carrying ability and temperature range are approximately those of babbitt, with considerably better abrasion-resistance. Both gears and sleeve bearings of nylon tested in the presence of abrasive materials, such as sand, have outworn metal components by far, under the same conditions of test. Nylon has a tendency to completely embed abrasive particles, sealing over the craters, and thereby restoring the bearing surface. In actual practice, nylon gears and bearings seldom fail from abrasive wear. Failure is the result, rather, of overheating, which can be prevented by design and by lubrication.

EASE OF LUBRICATION. Depending on conditions, nylon bearings can be effectively lubricated with a wide variety of solutions, or can be run quite successfully with no lubrication at all. Its ability to operate without lubrication has led to the extensive use of nylon by the textile industry, where contamination of product by oil has long been a problem. A similar field of application is in food-handling machinery and packaging machines.

Table I—Properties of Molded Nylon (FM-10001)

Property	Units	Values	ASTM Method
Tensile strength, −70F	psi	15,700	D638-44T
77F	psi	10,900	D638-44T
170F	psi	7,600	D638-44T
Elongation, −70F	percent	1.6	D638-44T
77F	percent	50	D638-44T
170F	percent	320	D638-44T
Modulus of elasticity, 77F	psi	400,000	D638-44T
Shear strength	psi	9,600	D732-43T
Impact strength, Izod, −40F	ft-lb/in.	0.4	D256-43T
77F	ft-lb/in.	1.5	D256-43T
Stiffness, 77F	psi	300,000	D747-46T
Flexural strength, 77F	psi	14,600	D790-44T
Compressive stress at 1% deformation	psi	4,900	D695-44T
Creep in flexure		90	Arl. P-25(1)
Hardness, Rockwell		R118	D785-47T
Flow temperature	F	>480	D569-44T
Coefficient of linear thermal expansion per F		5.5×10^{-5}	D696-44T
Thermal conductivity	Btu/hr/sq ft/F/in.	1.7	Arl. P-32(2)
Specific heat		0.4	
Deformation under load, 122F, 2,000 psi	percent	1.4	D621-44T
Heat distortion temperature, 264 psi	F	150	D648-45T
66 psi	F	360	D648-45T
Dielectric strength, short-time	v/mil	385	D149-44
step-by-step	v/mil	340	D149-44
Volume resistivity	ohm-cm	4.5×10^{13}	D257-45
Dielectric constant, 60 cycles		4.1	D150-45T
10^3 cycles		4.0	D150-45T
10^6 cycles		3.4	D150-45T
Power factor, 60 cycles		0.014	D150-45T
10^3 cycles		0.02	D150-45T
10^6 cycles		0.04	D150-45T
Water absorption	percent	1.5	D570-42
Flammability	in./min	self-extinguishing	D635-44
Specific gravity		1.14	D792-44T
Mold shrinkage	in./in.	0.015	
Compression ratio		2.1	D392-38

(1) "Creep in flexure" is a measure of the deformation under a prolonged standard load. Results here represent mils deflection in 24 hr of a ⅛ x ½ in. bar, 4 in. span, center-loaded flatwise to 1,000 psi, minus the initial deflection.

(2) Thermal conductivity measured by Cenco-Fitch apparatus.

Cost

It is difficult to give a direct comparison of parts in nylon and in conventional materials, because of the many factors affecting costs. Although nylon is one of the most expensive of the thermoplastics, its low specific gravity makes it compare very favorably, in material cost, with brass, bronze and similar materials commonly used for bearings and gears. Table II

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Table II—Density of Nylon And Other Bearing Materials

Material	Density (lb per cu ft)
Nylon	71
Laminated Phenolic	84
Aluminum 2S	169
Wood's Metal	605
Copper	530
Bronze	548
Brass	535
Zinc	417
Steel (1% C)	488
Cast Iron	455
Stainless Steel	483
Babbitt (95% Pb)	684
Babbitt (Sn/Cu/Sb)	462
Powdered Iron	474
Powdered Copper	530
Powdered Bronze	548
Powdered Stainless Steel	483

shows a comparison of nylon with a number of other bearing materials on the basis of density; it is apparent how this would affect a similar comparison on the basis of volume per dollar. Whether injection molded for large-volume applications, or machined from stock shapes, the cost picture for nylon parts is a bright one. As will be shown, improved performance is usually obtained at lower cost when nylon can be adopted.

Bearing Tests

To investigate the performance of nylon as a bearing material, tests of bearing load and wear rate were conducted, using the Neely boundary film machine so that conditions could be carefully controlled. These tests were run with oil and water as lubricants, under various conditions of loading, at a number of different rubbing velocities. Wear-plate combinations of nylon-nylon, nylon-brass and nylon-steel were evaluated. Distilled water, SAE 10 motor oil at a temperature of 125 F, and SAE 30 motor oil at room temperature were used as lubricants. Dry tests were also run on all the combinations at 88 percent relative humidity. Wear rate was checked at half-hour intervals. The coefficient of friction was measured at the beginning and end of each test run.

For the combination of nylon and cold-finished steel, with water as lubricant, loaded at 1,050 psi, with a rubbing velocity of 156 fpm, wear rate per half hr averaged 0.0092 in. Coefficient of friction averaged 0.494.

For nylon and cold-finished steel with SAE No. 10 as lubricant, loaded at 1,550 psi, with a rubbing velocity of 156 fpm wear per half hr averaged 0.005 in., with an average coefficient of friction of 0.140.

Running dry at 80 percent relative humidity, combinations of nylon and nylon showed half hr wear rate of 0.0016 in., and coefficients of friction from 0.039 to 0.099 at a load of 1,050 psi. When the load was reduced to 510 psi, wear rates were reduced below the measurable point or to only slight wear.

A small number of tests of the wear and friction of nylon were made at a higher rubbing velocity, 910 fpm (instead of 156 fpm). The time rate of wear and the coefficient of friction were quite similar to those found at 156 fpm. However, since the velocity was increased nearly four times, the rate of wear based on the amount of sliding was less at the higher velocity.

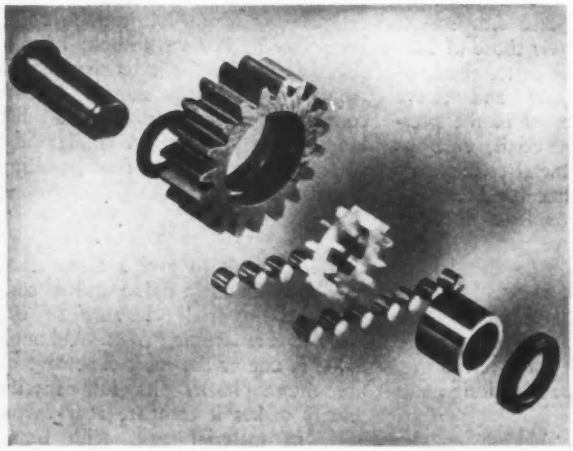
It was found the rates of wear are initially high, but rapidly decrease as the test progresses. As the nylon specimens wear in, the surfaces become polished, more intimate contact is established, unit pressure goes down and rate of wear decreases. The coefficient of friction becomes less as running continues, up to about 4 hr. After this period it usually remains constant. The rate of wear appears to become minimum after about 0.001-0.002 in. has been removed from the surface of the nylon. From tests against steel and brass, it appears probable that this amount of nylon must be removed to smooth the steel or brass enough so that it does not wear the nylon specimen further. This condition applies mainly to machined, unpolished surfaces, and is not so evident when molded bushings having a polished surface are run against a smooth shaft.

During the tests with water lubrication, wear rates increased when wear debris, suspended in the water, was allowed to remain in the bearing during the test period. Hence it is recommended that when water is used as a lubricant, there be sufficient flow of water through the bearing to assure removal of wear debris as formed.

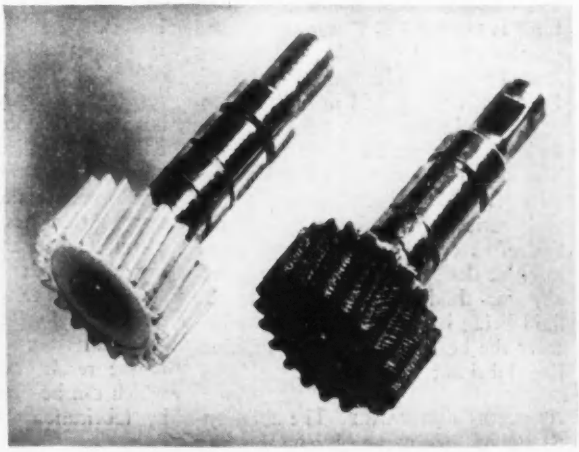
Combinations of nylon and nylon generally gave the lowest wear rate and lowest coefficient of friction, nylon and steel were almost as good, and nylon and brass was the poorest combination tested. Where corrosion is a problem, it is recommended that stainless steel be employed, rather than brass or bronze.

In the Neely machine, since the specimen is in contact with the wear plate for only 10 percent of the cycle, frictional heat does not become a factor in the test.

In actual sleeve bearing tests, using various shaft materials, steel appeared to be the best. Nylon bearings against shafts of cold-drawn steel supported loads as high as 206 psi, the load limit of the test equipment for a 1¼ in. dia bearing, at a rubbing velocity of 525 fpm. Since many of the specimens



NYLON BEARING CAGE helps this improved pinion assembly increase service life of Bell helicopter transmission.



REPLACING a laminated phenolic gear (right), the new Ford speedometer takeoff drive gear is molded of nylon.

tested on this equipment were carried to failure, definite maximum limits for loads and speeds have not as yet been established for nylon bearings. However, the single over-all limiting factor that determines the maximum capacity of a given bearing installation is the equilibrium temperature at the bearing face under operating conditions.

Upper limits of loads and speeds for nylon bearings can be extended by providing for the dissipation of frictional heat, either by the use of ample lubrication or by the design of the bearing and mounting. Exceptionally long service life may be expected from a bearing or gear installation where the temperatures of the contact surface are stabilized well below the heat distortion point. Surface temperatures up to 250 F are considered satisfactory. Temperatures above 300 F have been successfully tolerated where loading has not been excessive.

The effect of wall thickness of the bearing on the problem of avoiding excessive temperature is well illustrated by a series of tests, in which a surface speed of 525 fpm was maintained with a bearing load of 206 psi. The lubricant was SAE 10 motor oil. Of two typical samples, one bearing with a wall thickness of 0.125 in. failed by melting after running 240 hr. Under identical conditions, the companion specimen, with a wall thickness of 0.020 in., showed no indication of failure at the end of 361 hr of operation. Additional tests, with water as lubricant and without lubrication, showed the same difference in performance of thick- and thin-walled bearings.

Several factors influence this difference in performance. Thin-section nylon moldings are more dimensionally stable than thicker sections, and are less affected by changes of moisture content and temperature. This better dimensional stability permits better control of operating clearances. A thick bearing wall introduces excessive thermal insulation between the bearing face and the mounting structure, and thus retards the dissipation of frictional heat.

In most bearing installations there is a definite limit to allowable shaft displacement, resulting from bearing wear, which is established by the point of interference of rotating parts with stationary structure. This is usually the controlling factor in determining minimum wall thickness for the bearing. It is suggested that the wall thickness of nylon sleeve bearings be held to the minimum that will safeguard the mounting recess from damage in the event that maximum wear is experienced.

When to Lubricate

Water is a satisfactory lubricant for nylon, but not as good as a high-grade motor oil, and it imposes more stringent limitations on bearing capacity. When however, it is desirable or necessary to employ water as a lubricant, this loss of bearing efficiency must be justified on the basis of the imposed conditions. The same reasoning applies to the use of unlubricated bearings, bearings running in milk, gasoline, solvents or other unorthodox lubricants. The use of ineffective lubricants has an adverse effect on the service life or capacity of a bearing, but this decrease in efficiency is much less with nylon than with other materials. Nylon is thus considered an excellent material for use under adverse conditions of lubrication.

In unlubricated bearings, the initial break-in period is very critical if they are run at or near their maximum capacity. The ultimate service life of unlubricated bearings can often be appreciably extended by using limited quantities of lubricant during the first few hours of operation. Usually an application of light oil or grease at the time of installation is sufficient to protect the bearing during the break-in period.

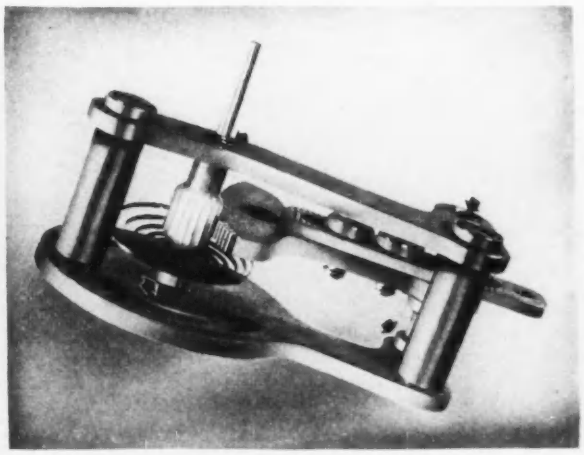
In general, excessive loading, extreme speeds, inadequate lubrication, poor mounting, or a combination of these factors results in terminal temperatures above the heat distortion point of the nylon, which then causes what is commonly called "galling". Proper design will avoid this condition if the proposed application is within the practical range of nylon.

Fabrication Of Mechanical Parts

To avoid the expense of dies necessary to mold limited quantities of parts, they are usually machined from stock sections of molded nylon. Tests indicate little or no difference in performance between molded and machined pieces, and it can generally be assumed, if experimentally machined test parts show satisfactory performance, that well molded parts will perform with equal satisfaction.

Nylon can be readily machined with conventional machine-tool equipment. In general, procedures used in machining free-turning yellow brass will give satisfactory results with nylon. High-speed steel or tungsten carbide tools give superior results, because of their ability to maintain a sharp cutting edge. As with metals, carefully honed edges are essential if accuracy and high finish are desired.

Tools should be ground with sufficient clearance to avoid drag and possible overheating of the work. A coolant, such as standard soap solution or



PINION GEAR and four bearings of this new pressure gage are molded of nylon, which has low coefficient of friction.

SPECIAL TECHNIQUE is used to install nylon bushings in die-cast metal parts, giving accuracy at low cost.

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cutting oil, is often helpful in working to close dimensions and in producing a high finish.

High cutting speeds with low rates of feed are desirable. Although nylon is not nearly as sensitive to heat as most of the other thermoplastics, care must be exercised to avoid overheating, which may result in gumming and consequent surface damage. Nylon can be turned, drilled, tapped, milled or sawed, by adhering to machine practice used for the softer metals.

Although difficult to file by hand, nylon grinds readily. A soft wheel is used, with water as a coolant. A curve-toothed milled file can be used for certain types of work, such as developing irregular contours on lathe-turned pieces.

Nylon can be given a high finish by wet sanding or ashing with pumice and water, followed by buffing on a standard cotton wheel. Conventional stick compounds can be used to dress the wheel. Finish-buffing on a clean wheel dressed lightly with tallow produces a high gloss.

EXPERIMENTAL PARTS. Because of the relatively high coefficient of expansion of nylon, precision measurments should be made only when the material is at room temperature. To gain maximum dimensional stability in precision parts machined from thick sections of nylon, they should be treated to ren ve strains. The effect is much the same as that experienced in the machining of sand castings of iron. Whereas the strain is in equilibrium in the original molded shape, the removal of stock by machining develops an unbalanced condition which may cause subsequent warpage or an increase in size of the finished piece.

To avoid such difficulty, parts should be rough-machined to within approximately $\frac{1}{32}$ in. of finished dimension and then soaked in plain water at room temperature, for about 24 hr per $\frac{1}{8}$ in. of maximum wall thickness. Since water is an excellent "plasticizer" for nylon, such soaking will effect an almost complete release of residual strain, and yield a finished part of maximum dimensional stability. To restore the piece to normal moisture equilibrium after soaking, it should be dried in an air oven at approximately 160 F (70 C) for a time equal to the soaking period. It can then be machined to finished dimension.

Bearing Applications

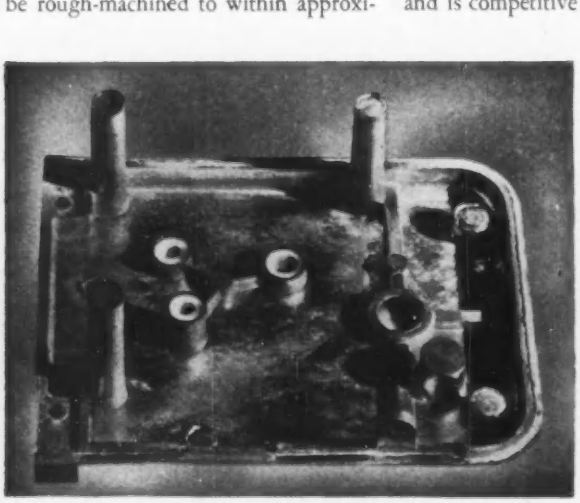
Nylon played a significant part in solving a critical transmission problem in the Bell Model 47 helicopter. Engine power is applied to the main rotor through a two-stage planetary reduction unit. Considerations of both weight and space preclude the use of conventional bearings in this unit. After service-testing a number of bronzes, steels and a phenolic composition without complete success, Bell engineers tried nylon roller cages and found them entirely satisfactory. Service life of the bearing assembly was extended from 25 hr in the original design to 300 hr in the final design, an increase of 1,200 percent. Bell engineers list the following reasons for using nylon in this application: (1) It is light in weight, hence keeps centrifugal loads to a minimum; (2) it has good wearing properties when rubbing over a ground steel surface with marginal lubrication; (3) it is homogeneous, and hence retains good physical properties in light sections; (4) it is elastic, allowing the energy of impact loads to be absorbed by displacement; (5) it can be injection molded and is competitive in cost.

An unusually severe bearing application of nylon is in the new Apex washer which utilizes a new operating principle. During the wash and the two rinse cycles of the machine, the inner basket "bounces" back and forth at the rate of 550 pulsations per min, to flex and flush the clothes. During the water-extraction cycles this same 21-in. basket spins on a vertical axis at 550 rpm. In the original design a steel universal joint was employed to create this motion. Being a precision part, it was expensive to make. It required extensive machining and grinding, special heat treatment, and a special lubricant. Moreover, it was noisy in operation. A single molded nylon yoke pin replaced the two steel pins of the old design, with a significant saving in cost, great reduction in noise and elimination of the lubrication problem.

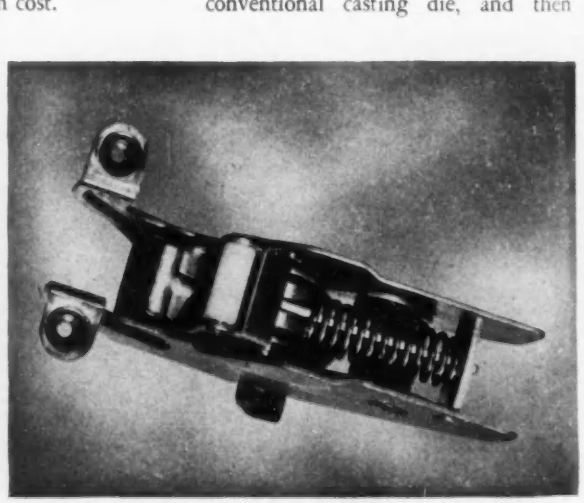
Most domestic refrigerators have nylon bolt rollers in their doorlocks. The necessity of lubricating conventional metal door-lock rollers results in a film of lubricant on the exposed areas of the mechanism, which is a soilage hazard to the user. With nylon it is unnecessary to use any lubricant between the bolt roller and the bolt roller pin. After a fatigue test of 500,000 cycles, wear on the nylon rollers was found to be practically nil.

The properties of nylon have been utilized in a similar way in door and cabinet catches. Nylon latch bolts provide longer wear and quieter operation than conventional metal bolts. Also, they require no lubrication and are not subject, like metal lock parts, to corrosion, with resultant sticking.

A technique for the installation of nylon bushings in die cast metal parts has been developed by Minneapolis-Honeywell. By positioning injection molded nylon bushings on pins in a conventional casting die, and then



MOLDED NYLON BOLT ROLLERS used in refrigerator locks outwear stainless steel, and cost from 15 to 35 percent less.



LONGER WEAR and quieter operation are obtained from molded nylon latch bolts than from conventional metal bolts.

shooting molten zinc alloy into the die under pressure, the nylon is welded into place in the finished piece. A high order of accuracy in placement and size of the nylon bushing is thus achieved at a minimum cost. This has proven by far the most practical way of using extremely thin wall sections, which permit dissipation of heat into die cast metal, and thus the nylon bushings can be run at higher speed without excessive heating. This technique opens a broad field for nylon bearings in radios and automatic phonographs, toy trains and other mechanical toys, motor bearings, clock mechanisms and similar applications where assembly cost has precluded the use of durable bearings because of the hand labor involved in their installation.

Gear Applications

The ability of nylon to damp mechanical vibration will frequently prevent annoying noise in gear trains and will tend to reduce the resonant torsional vibration which is particularly objectionable in motion-picture and sound-recording equipment. The quietness of nylon gears may be one of the principal reasons for using them in light machines for household use.

Nylon is used in gears in the new household egg-beater produced by Ekco Products Company. Comparative wear tests show that these injection-molded nylon beater gears will last over ten times as long as the former die-cast gears. Injection-molded nylon gears are accurate in dimension and compare very well in cost with die-cast gears. The use of color in the nylon gears adds to the sales appeal of the finished product. These gears are unaffected by the salad oils and various materials with which they come in contact. They operate efficiently and quietly without lubrication of any kind.

Combining bearing strength with water-stability, nylon is used in the Metco lawn sprinkler, which is activated by power from a high-speed impulse turbine driven by the flow of water through the sprinkler. A double-reduction worm-gear set, running in water, is used to reduce the high speed of the turbine to approximately 4 rpm, with a torque of about 5 in.-lb. The output shaft of the gear system actuates the sprinkler tube through a simple crank mechanism. Two nylon gears are used in the system, running against two brass worms. Nylon was chosen for the gear because of its strength, durability and efficiency when used with water lubrication. Economies were effected by injection molding.

A series of molded nylon parts used in the Monroe calculator give an illustration of molding precision parts at low cost. Nylon is used for counting-dials, cams and ratchets. On the first two parts, the change to molded nylon reduced the number of production steps from 33 to 4, and gave an overall cost saving of 67 percent. The third part, a new ratchet of improved design, proved so intricate as to be possible only in molded nylon. Molded to tolerances as close as 0.005 in., these parts, after performance tests running millions of cycles beyond the expected service life, showed little evidence of wear.

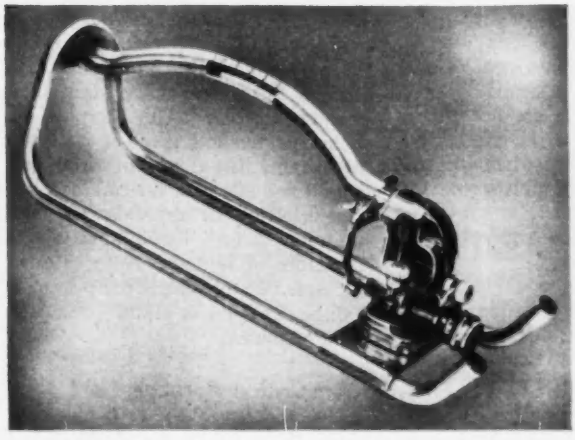
By replacing a laminated gear with nylon, Ford has achieved an 80 percent reduction in production cost and obtained a part superior in performance to the one replaced. With the former part, a backing washer and then the gear blank were assembled to the shaft, teeth were hobbed in the blank, and tooth identification was stamped on the side of the gear in a manual operation. The nylon gear, complete with tooth identification, is molded directly on the shaft in one operation. The backing washer has been eliminated. Closer tolerance can be maintained, and superior wear-resistance is obtained. The nylon gear has been tested successfully at 80 mph for the equivalent of 100,000 miles.

Both gears and bearings of nylon are incorporated in a chemical pressure gage made by Manning, Maxwell and Moore. The key part of the movement is a nylon pinion gear, which imparts positive action with respect to the pressure element of the gage. Nylon is used because of its unique combination of low coefficient of friction, chemical resistance, and wearing qualities, plus the fact that it absorbs vibration without transmitting it to other parts. Four small bearings also are made of nylon for the same reasons.

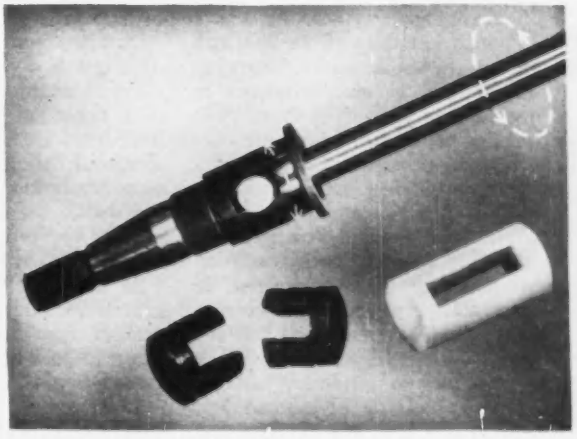
Small nylon pinion gears drive the rotating shutters of the Revere 8- and 16-mm motion-picture cameras. These gears, traveling at speeds from 1,000 to 3,000 rpm, absorb shock in gear trains that must start freely and stop suddenly, and provide quiet operation. In addition to the pinion gear, the 8-mm camera has an intermediate pin gear (over one in. in dia) with helical teeth, which travels at 400 rpm. This part is machined from a molded nylon blank, eliminating screw-machine parts and assembly time. The 16-mm camera uses a face gear of nylon, also machined from a molded blank to a tolerance of $\pm$ 0.0005 in. This gear is press-fitted onto a metal shaft.

Other Uses

Although this article has been specifically concerned with bearing and gear uses, electrical properties of nylon should not be overlooked. Nylon is commonly molded into coilforms, terminal blocks, insulating washers and sleeves, and components of coaxial cables—parts in which mechanical as well as electrical properties are utilized.



DOUBLE-REDUCTION WORM GEAR SYSTEM in the Metco lawn sprinkler uses two molded nylon gears for water-stability.



ONE-PIECE MOLDED NYLON YOKE PIN, replacing two steel pins in new Apex laundry unit, reduces cost and noise.

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Critical Buckling Loads For Hydraulic Actuating Cylinders

Procedure for computing critical buckling loads for hydraulic actuators that consist of a cylinder and piston rod where compression force is transmitted over part of the column length by fluid pressure. Buckling loads are analyzed using moments and forces acting on a free body with cylinder fluid both included and excluded.

FRED HOBLIT
Stress Engineer, Lockheed Aircraft Corporation

WHEN THE DIAMETERS of a hydraulic actuating cylinder and piston are small in comparison with the extended length of the cylinder and piston, failure under load is likely to be by column buckling. Since the compression force is transmitted over a part of the cylinder length by fluid pressure, such a device may appropriately be called a "fluid column."

Common examples of the fluid column are hydraulic jacks; actuating cylinders used in many airplanes to retract landing gears, to open and close bomb bay doors, and to operate control surfaces through booster mechanisms; and cylinders used to position blades in earth moving equipment.

In spite of the fairly common use of the fluid column, much confusion exists regarding the determination of its strength. Frequently, its strength is considerably overestimated and the result is an unsafe structure. When the principles of ordinary column buckling are clearly understood and the peculiarities of the fluid column are recognized, the determination of the buckling load for a fluid column is as straight-forward as for any other column.

A typical fluid column, such as shown in Fig. 1, comprising an actuating cylinder, piston, and piston rod, differs from the simple Euler column in three respects:

1. The axial load is transmitted over part of the length of the column by fluid pressure.

2. The column is stepped; that is, its length is divided into two parts of different moments of inertia.

3. These two parts are not rigidly joined but are joined, in effect, by a rotational spring, since when the column bends the small portion of the rod within the cylinder, as shown in Fig. 1(*B*), can bend independently of the cylinder.

In analyzing such a column, two general methods are possible. These parallel those for a simple Euler column. In both cases, the column is regarded as pin-supported at both ends.

1. Treat the member as a pure column without eccentricity to find the critical load P_{cr} at which the column will buckle. This procedure is comparable to that ordinarily followed for the simple structural column except that for the structural column it is customary to think in terms of stress rather than load. The actual mechanism of column buckling involves load, not stress; and for a stepped column, load cannot conveniently be expressed as stress because the cross-sectional area is not constant.

2. Treat the member as a beam column, taking account of eccentricities and initial deflections resulting from manufacturing tolerances, and determine stresses and margin of safety at the most critical point in the member.

Which of these methods should be used for any particular design is a matter of judgment. It is believed, however, that the eccentricities in most fluid columns are not sufficiently great to necessitate treatment as a beam column. (One design, typical of aircraft applications, showed 5 percent difference in allowable load.)

Even in the rather rare instances when a beam-column analysis is to be made, it is usually necessary to obtain the pure-column buckling load P_{cr}. A stepped beam column is difficult to analyze precisely. The accepted approximate method involves analyzing the member first as a beam without the magnifying effects of the end load, and then applying an approximate "magnification factor" based upon P/P_{cr}. Therefore, it is necessary to calculate P_{cr} regardless of whether the member is to be regarded as a pure column or a beam column.

Critical Buckling Load

Considerable confusion exists regarding the effect of the fluid on the magnitude of the critical buckling

load P_{cr}. Actually, there is no difference whatever in the critical buckling loads for a fluid column and a solid column when they have the same flexural rigidity EI, section for section, along their length. In investigating the effect of the fluid, the problem is simplified slightly by neglecting the "spring connection" between the cylinder and the rod, Fig. 1(B); that is, by assuming the deflection curve not to have a sudden change of slope at the change of column section.

The basic method for finding P_{cr} of any kind of column is to give the column a very small deflection, shown greatly exaggerated in Fig. 2. In solving the differential equation expressing the condition of static equilibrium at all points along the column, it will be found that deflections different from zero or infinity can occur only for a certain value of P. This value of P is the critical buckling load P_{cr}. At this load, as the member deflects, the internal bending moment increases at exactly the same rate as the applied moment produced by the end load, so that the member is in equilibrium at any deflection, so long as the material is not stressed sufficiently to produce local failure.

For any end load greater than P_{cr}, if the member is given any deflection, no matter how small, the applied bending moment will always be greater than the resisting moment and the deflection will increase until failure results. For any load less than the equilibrium load, the applied moment is always less than the resisting moment and the member, therefore, will always tend to return to the straight position.

Free Body Equations

To obtain the differential equation for the fluid column, it is necessary to cut the member at an arbitrary point x, Fig. 3, and "isolate" or "draw a free body diagram" of everything on one side of the cut. The free body diagram may be drawn either to include, Fig. 3, or exclude, Fig. 4(A), the fluid.

If the fluid is included, Fig. 3, the condition of equilibrium, taking moments about A, is

$$Py = M_b \qquad (1)$$

where M_b is the internal moment applied by the removed portion of the column. Since this moment cannot be applied by the fluid, which is under uniform pressure, it must be applied by the cylinder. The cylinder bends in response to the moment according to the familiar equation,

$$\frac{1}{\rho} = \frac{M}{EI} \text{ or } -EI\frac{d^2y}{dx^2} = M \qquad (2)$$

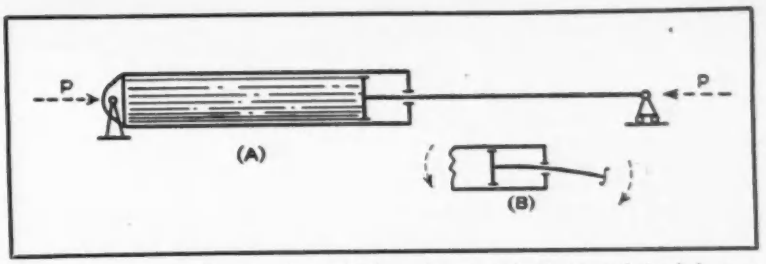

Fig. 1—(A) Hydraulic actuating cylinder, piston, and piston rod loaded as a column. (B) Portion of rod within cylinder can bend independently of cylinder.

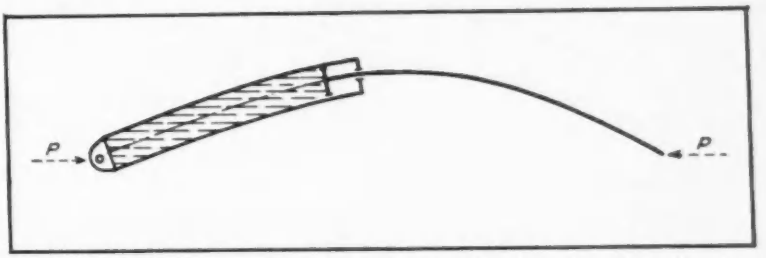

Fig. 2—The first step in determining the critical buckling load of a column is to give it a small deflection and establish an equation for equilibrium.

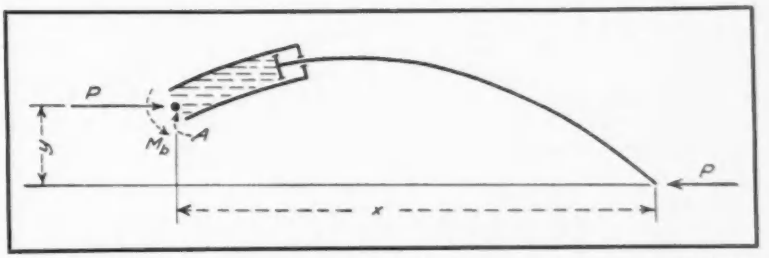

Fig. 3—Column is cut at an arbitrary point to determine the moments and forces acting on a free body when cylinder fluid is included in the free body.

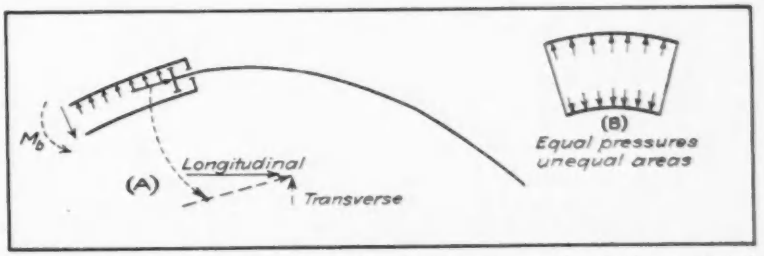

Fig. 4—(A) Moments and forces on free body when cylinder fluid is excluded. (B) Unbalanced lateral force produced by fluid pressure when cylinder bends.

Substituting Eq (2) in Eq (1), gives the differential equation

$$Py + EI\frac{d^2y}{dx^2} = 0 \qquad (3)$$

Exactly the same differential equation is obtained for a solid column, and consequently the same formula for P_{cr}. This conclusion should seem reasonable, since column buckling is essentially a bending rather than a compressive phenomenon, and the bending resistance is entirely in the solid part of the column.

If the free body diagram is drawn with the fluid excluded, Fig. 4(A), the mathematics become more formidable. The fluid pressure exerts an unbalanced lateral force when the cylinder bends, Fig. 4(B). In addition, the fluid pressure acting on the interior face of the piston has a transverse as well as a longitudinal component.

For a very small deflection these additional forces, of course, are very small. But the moment arm through which the load P acts is likewise very small. The moments produced by all three sets of forces are of the same order of magnitude and none may be

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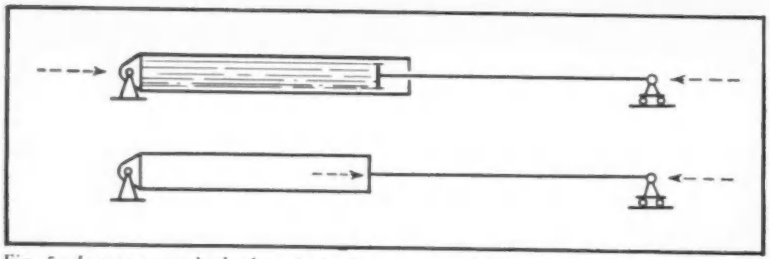

Fig. 5—Incorrect method of analysis that assumes the column is solid and loaded at the piston by the fluid and that the load is applied in a longitudinal direction.

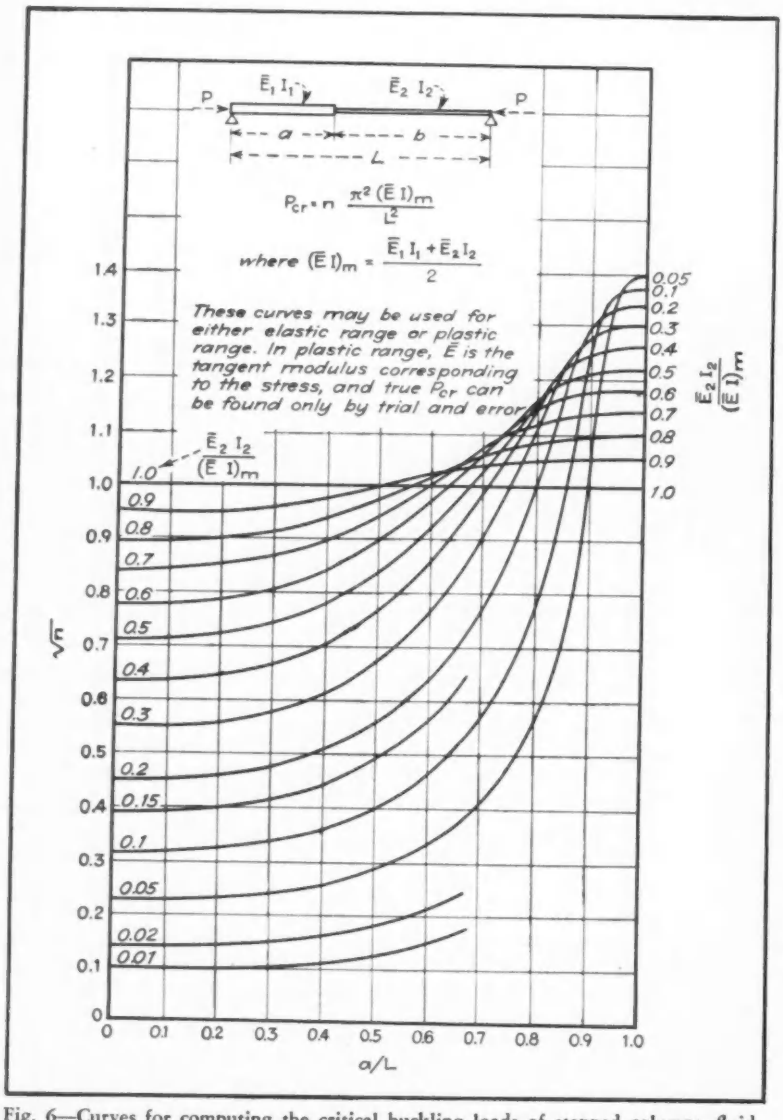
P
$\bar{E}_1 I_1$
$\bar{E}_2 I_2$
P
a
b
L
$P_{cr} = n \frac{\pi^2 (\bar{E} I)_m}{L^2}$
where $(\bar{E} I)_m = \frac{\bar{E}_1 I_1 + \bar{E}_2 I_2}{2}$
These curves may be used for either elastic range or plastic range. In plastic range, $\bar{E}$ is the tangent modulus corresponding to the stress, and true P_{cr} can be found only by trial and error.
$\frac{\bar{E}_2 I_2}{(\bar{E} I)_m}$
$\sqrt{n}$
$\frac{\bar{E}_2 I_2}{(\bar{E} I)_m}$
a/L

Fig. 6—Curves for computing the critical buckling loads of stepped columns, fluid or solid, with rigid connection at step. Curves are based on data in NACA TM 861.

neglected if the correct result is to be obtained. When all these forces are included, a differential equation is obtained that can be reduced to Eq (3), which as shown is readily obtained by simply including the fluid in the free body diagram.

It must, therefore, be concluded that P_{cr} for a fluid column is exactly the same as that for a solid column of the same moment of inertia. There is one exception to this rule. If a solid column is stressed beyond the proportional limit, in the formula for P_{cr} the value for E must be taken as the tangent modulus.

For the fluid column, however, there is no axial stress in the cylinder, but instead a hoop tension stress. The effect of a transverse stress on the longitudinal stress-strain curve does not seem to be known with certainty. There would, however, manifestly be a difference in the behavior of the two columns if the cylinder were in the plastic region. Fortunately this condition seldom occurs in practice.

In spite of the rather conclusive logic presented in the foregoing discussion, arguments are sometimes put forth in an attempt to justify methods of analysis that give incorrect values of critical load. As these arguments often appear convincing, two of them will be considered in detail.

One argument is that an entire column filled with fluid would be like a pipe with sealed ends and pressure applied by an external pump. Obviously, such a column would never buckle; hence the all-fluid column will never buckle. The fallacy is apparent. The closed pipe has a longitudinal tension stress in the cylinder wall, which does not exist for the fluid column. This longitudinal tension force provides a stabilizing effect that is exactly equal to the destabilizing effect of the compression load carried by the fluid.

The fallacious premise that the fluid column is no more likely to buckle than a closed pipe, incidentally, could lead to a rather absurd conclusion. If this premise were correct the pipe could then be replaced by a flexible hose and fitted with a piston at one end, and the result would be an effective compression member!

A more subtle, but none-the-less incorrect, proposal is to treat the fluid column as a solid column loaded at the piston by the fluid, Fig. 5. This method of analysis gives higher values of critical load than the correct method (by about 45 percent in one typical case). The proposal takes account of the bending stiffness—or flexibility of the tubular portion, but assumes, incorrectly, that the load is applied only to the piston and in a longitudinal direction.

The fallacy in this assumption, is that as the column deflects, two additional loads, which were discussed previously and shown in Fig. 4, begin to act. These are a transverse component of the fluid pressure on the piston and an unbalanced lateral force resulting from the bending of the cylinder. Although for small deflections these added forces are very small, the bending moments they produce are of the same order of magnitude as that produced by the end load P acting through its very small moment arm. Since buckling results solely from the bend-

ing effect of the applied loads, if the bending effect of these two added forces is neglected an incorrect value of critical load is to be expected.

It will be noted, furthermore, that in the typcial example discussed the neglected forces are both destabilizing, so that the incorrect method leads to an unsafe, rather than an over-strong, design.

Fluid Column Formulas

1. For a stepped column, fluid or solid, with rigid connections at the step, where

L = overall length of column, in.
a = length of the portion of column at the cylinder end, in.
b = length of the portion of column at the rod end, in.
I_1 = rectangular moment of inertia of cylinder portion
E_1 = modulus of elasticity of material in cylinder portion
I_2 = rectangular moment of inertia of rod portion
E_2 = modulus of elasticity of material in rod portion
$(EI)_m = (E_1I_1 + E_2I_2)/2$

the critical load P_{cr} can be obtained from the curves and formula given in Fig. 6, which are reproduced from NACA TM 861 but in a more usable form.

2. When the spring connection between the piston and rod is to be included, Fig. 7(A), the following formula for P_{cr} can be used:

$$P_{cr} = \frac{(3L/ab)\ K_1\ K_2}{K_1\ \beta_2 + K_2\ \beta_1 + (K_1\ K_2/K_e)} \quad (4)$$

The terms in Eq (4) are

$$K_1 = E_1 I_1/a \qquad K_2 = E_2 I_2/b$$

$K_e = M/3\theta$, where θ is the angle of rotation, Fig. 7(B), produced by a moment M on the rod, radians. If the rod is simply supported at both the gland and the piston, $K_e = E_2I_2/d$, where d is the length of rod in inches between piston and cylinder joint.

$$j_1 = \sqrt{E_1 I_1/P} \qquad j_2 = \sqrt{E_2 I_2/P}$$

$$\beta_1 = \frac{3\,[1 - (a/j_1)\cot(a/j_1)]}{(a/j_1)^2}$$

$$\beta_2 = \frac{3\,[1 - (b/j_2)\cot(b/j_2)]}{(b/j_2)^2}$$

The terms a/j_2 and b/j_2 are considered to be angles in radians when obtaining the cotangents. Values of β_1 and β_2 for a/j_1 and b/j_2 respectively are given in Table 14:2 of Niles and Newell, "Aircraft Structures."

In the plastic range, E_1 and E_2 must be replaced by the tangent modulus. For a fluid column, the cylinder must remain in the elastic range, since no method is available for obtaining E_1 in the plastic range for a fluid column.

The formula Eq (4) must be solved by trial and error, since β_1 and β_2 depend upon j_1 and j_2, which depend upon P. As obtained from the formula Eq (4), the value of P_{cr} is correct when it is equal to the assumed value of P. The data given in Fig. 8 are useful in obtaining a value for P for a first trial, or a series or trials.

An indication of the amount of reduction in critical load resulting from the presence of the spring joint is given by Fig. 8, which represents a typical aircraft application.

Ultimate Margins of Safety

PURE COLUMN ANALYSIS. Two margins of safety must be obtained to determine whether the fluid column will fail at ultimate applied load, assuming that failure will be as a pure column. In checking any structure for adequate strength, it is necessary to compare the applied load with the allowable load. In aircraft stress analysis, the "margin of safety" is customarily used to express this comparison quantitively.

1 The usual column margin of safety must be obtained:
Where

P = applied ultimate axial load, lb
P_{cr} = buckling load, determined according to the preceding discussion, lb
M_s = margin of safety
$M_s = P_{cr}/P - 1$

2. In addition, to preclude yielding of the cylinder at ultimate load (to fulfill the assumption of an elastic cylinder, necessary in obtaining P_{cr}, and because the cylinder will buckle to fail-

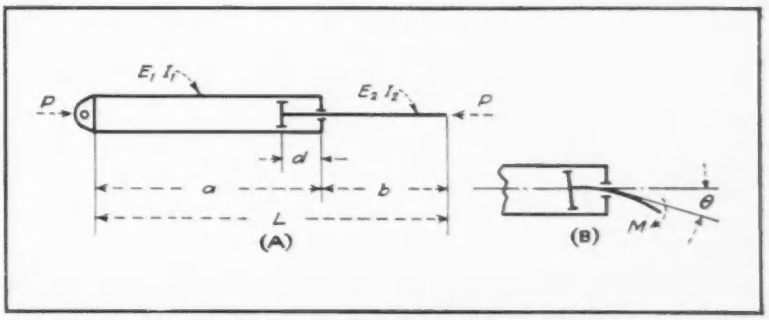

Fig. 7—(A) Notation used in formula for computing critical buckling loads of stepped columns when spring connection between piston and rod is included. (B) Angle of rotation produced by moment at connection between piston and rod.

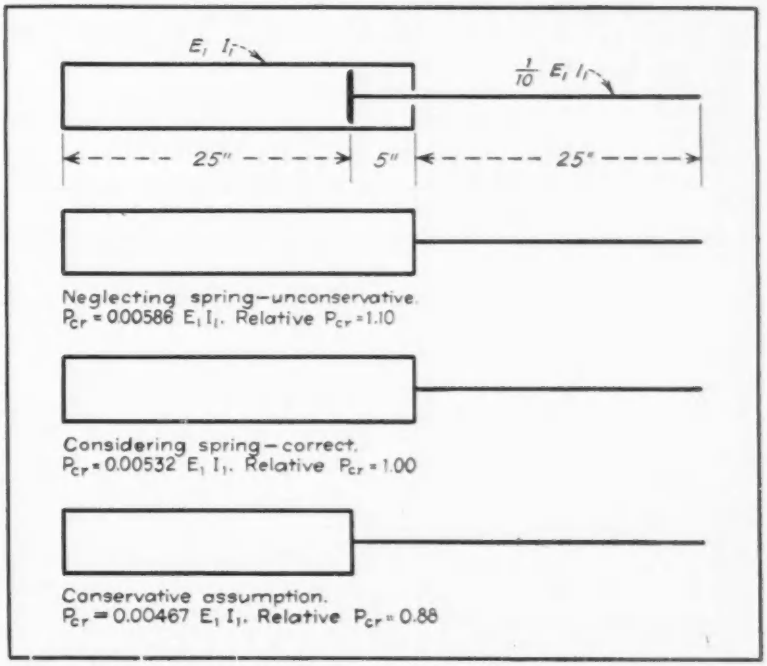

Fig. 8—Comparison of critical loads for a hydraulic cylinder, used in an aircraft application, as computed with and without inclusion of spring connection.

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ure approximately at the yield stress) the following M_s must be computed:

Where

f_{htu} = applied ultimate hoop tension stress, psi
F_{ty} = tensile yield stress, psi
$M_s = F_{ty}/f_{htu} - 1$

TREATMENT AS A BEAM COLUMN. Although for conventional actuating rod designs it suffices to make the ordinary pure-column analysis described in the preceding paragraphs, there may be times when it is desired to take full account of initial eccentricities or bearing friction by means of a beam-column analysis.

An approximate beam-column magnification factor

$$\frac{1}{1 - (P/P_{cr})}$$

is used to obtain bending moments produced by eccentricities.

In evaluating this factor, P_{cr} is not the actual buckling load of the pure column but is a recomputed value (if any part of this column was in the plastic range) obtained by using the tangent modulus corresponding to the applied load P rather than to P_{cr}.

This magnification factor gives surprisingly accurate results under certain conditions; but when applied directly to bending moment, it is grossly inaccurate if there is end eccentricity. With end eccentricity, the bending moment at the end is determined only by the external loading and cannot be magnified. The magnification factor, therefore, is applied to deflections rather than moments, according to the following procedure:

1. Draw a bending moment diagram for the column with the end load and any lateral loads applied, but with all parts of the column assumed rigid. Thus, the slack in the rod-cylinder joint is taken up but the rod does not bend inside the cylinder nor, of course, anywhere else.

2. Obtain the deflection curve, Fig. 9, that would result from the application of this bending moment diagram to the actual elastic column. This deflection curve may be obtained by any one of various methods. A simple graphical method that utilizes the conjugate beam concept is explained fully in Niles and Newell, "Airplane Structure," Vol. 1, 3d Ed., Chap. 9, pp. 249-252. In applying the conjugate beam concept, the effect of the spring connection joining the cylinder and rod may be incorporated by applying to the conjugate beam an additional concentrated load of $M/3K_c$ at the change in section. The deflections, y_2 in Fig. 9, thus obtained are displacements of the neutral axis from its original position.

3. Obtain the final deflection curve as shown in Fig. 9, by multiplying the deflection obtained in Step 2 by

$$\frac{1}{1 - P/P_{cr}}$$

4. Obtain final bending moments at critical sections by statics from the applied loads as located relative to this final deflection curve.

BEAM COLUMN MARGINS OF SAFETY. If it is desired to determine whether the fluid column will fail at ultimate applied load by the combined action of the compressive load and initial eccentricities, the following two margins of safety must be obtained.

1. Rod Portion. Margin of safety M_s is the same as for any other beam column:

Where

P and P_{cr} are the same as in the "pure column" analysis
f_b' = bending stress including beam column effect
F_b = bending modulus of rupture
$R_c = P/P_{cr}$
$R_b' = f_b'/F_b$

$$M_s = \frac{1}{R_c + R_b'} - 1$$

2. Cylinder. To preclude yielding of the cylinder at ultimate load (to fulfill the assumption of an elastic cylinder necessary in obtaining P_{cr}) and because the cylinder will buckle to failure approximately at the yield stress, the margin of safety is given by the following expression, in which all stress ratios are taken as positive.

Where

F_{ty} = tensile yield stress
f_{htu} = applied ultimate hoop tension stress
F_{by} = bending yield modulus (that is, the calculated My/I bending stress at yield, which in the absence of more precise data may be taken equal to F_{ty})
f_{bu}' = applied ultimate bending stress including beam column effect
$R_b' = f_{bu}'/F_{by}$
$R_{ht} = f_{htu}/F_{ty}$

$$M_s = \frac{1}{\sqrt{(R_b')^2 + R_{ht}^2 + R_b' R_{ht}}} - 1$$

This expression is based upon the maximum distortion strain energy criterion of yielding.

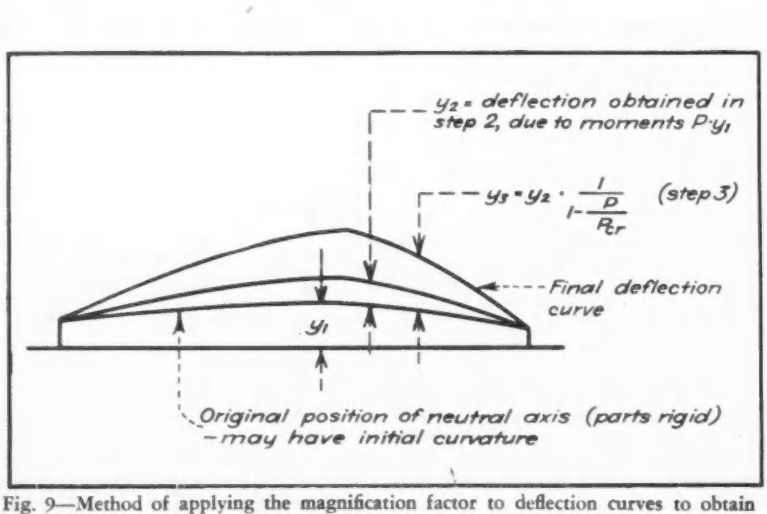
y_2 = deflection obtained in step 2, due to moments $P \cdot y_1$
$y_3 = y_2 \cdot \frac{1}{1 - \frac{P}{P_{cr}}}$ (step 3)
Final deflection curve
y_1
Original position of neutral axis (parts rigid) — may have initial curvature

Fig. 9—Method of applying the magnification factor to deflection curves to obtain final bending moments at critical sections.

Conclusions

1. The elastic buckling load for a fluid column is exactly the same as for a solid column having the same length and moments of inertia.

2. The buckling load of a fluid column when the cylinder hoop stress is in the plastic range cannot be predicted exactly by simple methods, but this condition ordinarily does not occur in practice.

3. Incorrect formulas for obtaining the buckling load of a fluid column have often resulted from the omission in the analysis of certain forces that are small in themselves yet important because of the relatively large moment arm through which they act.

4. The possibility that a fluid column can buckle at all has often been overlooked because it has incorrectly been regarded as identical to a sealed pipe under pressure. This analogy is incorrect because the sealed pipe has a stabilizing axial tension force that is not present in the fluid column.

5. In the practical stress analysis of a fluid column, the presence of the fluid should be disregarded, except for local stresses resulting directly from the fluid pressure. The resulting solid column is then analyzed by the same methods as would be appropriate for any other ordinary solid column, giving proper consideration to such factors as variation of moment of inertia, initial eccentricities, and springiness and slack in the rod-cylinder joint.

SENSING SMALL MOTIONS

1. With Variable Reactors

2. With Differential Transformers

T. R. BREUNICH
Project Engineer, Sonntag Scientific Company

IN RECENT YEARS, there has been considerable development in the use of coils and transformers with movable cores for detecting small motions. Coils and transformers of this type are generally called variable reactors and differential transformers, respectively.

The operation of these devices depends on the fact that their electrical characteristics are directly related to the positions of their iron cores. Because the inductance of a coil and the inductive coupling of a transformer are functions of flux density and distribution, and shift in core positions changes both the density and distribution of flux. Thus, when either a variable reactor or a differential transformer is included in a circuit, even the slightest variation in core position has a measurable effect on current flow.

In simple applications, the devices are connected to a calibrated meter for direct indication of the relative movement between core and coil. They are also widely used as sensing elements in control circuits. For example, a variable reactor can be made to trip relays that open a switch, ring an alarm or start a motor. Response is rapid and precise.

Characteristics of Typical Variable Reactor Circuits

There are two common types of variable reactors. In one type, the coil is wound on a non-magnetic ceramic tube or its equivalent. The iron core is located within the tube, as shown in Fig. 1(A). As the core moves in or out of the magnetic field, the inductance of the coil changes. The a-c current flowing through the circuit will vary accordingly. With a constant a-c supply voltage, there is a particular meter reading corresponding to each core position. The second type is similar in principle and has the coil wound on a core whose iron curcuit is not complete. The moving element, or armature, varies the air gap in the flux path as shown in Fig. 1(B), thus changing the coil reactance.

One common circuit arrangement for variable reactor applications is the Wheatstone bridge.[1] A reactor is incorporated in each of the legs on one side of the bridge. The other side contains a balancing resistor or potentiometer. Two such circuits are shown in Fig. 2(A). Once the bridge is balanced, any movements of the core or armature causes current to flow through the meter. For control purposes, contact closing meters or sensitive relays are used instead of the conventional meters; since contact closing meters are usually d-c, rectifiers are included on the resistor side of the bridge. The signal resulting from unbalance can be impressed on the grids of vacuum tubes for direction control.

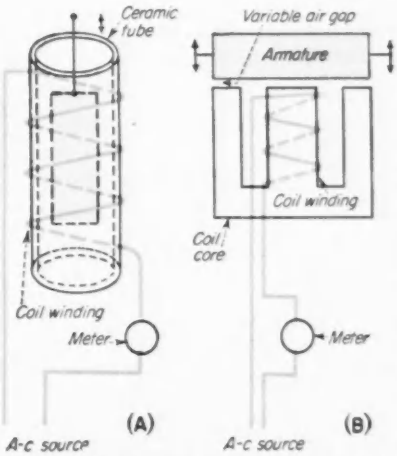

Fig. 1—(A) One type of variable reactor. Movement of the core changes the current flowing through the ammeter. Meter reading is therefore an indication of coil position. (B) Movable armature is part of the iron circuit in this type variable reactor. The armature is connected to the piece whose movement is to be measured.

One advantage of the bridge type circuit is that it permits the use of two reactors. A change in the position of the common core or armature has a compound effect on unbalance. The effective signal is thus double what it would be if only one reactor were employed. Also, in a bridge circuit, variation of coil impedance with temperature can be compensated for by potentiometer adjustments. Where only one reactor is used, compensation for temperature changes is difficult.

The bridge circuit eliminates the

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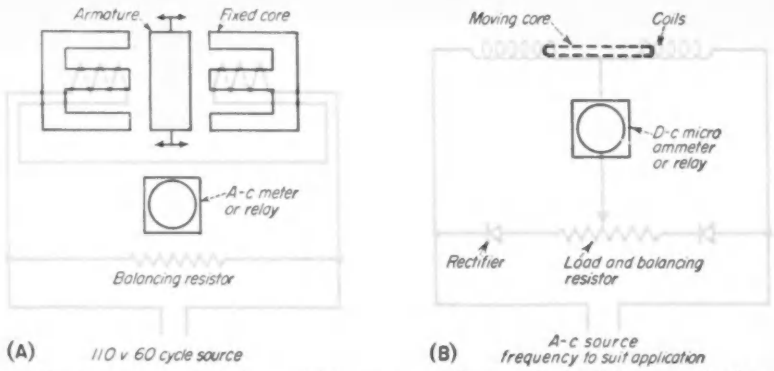


Fig. 2—A common circuit for variable reactor applications is the Wheatstone bridge. Because two reactors are used, the magnitude of the available signal is doubled. (A) Bridge circuit using a-c meter; (B) bridge circuit using d-c meter.

problem of stray field interference. Both legs pick up the same amount of "hash," the effect of which can be cancelled by potentiometer adjustments. Long leads of plain unshielded wire are satisfactory.

The coil and core units in a bridge connection, can be designed for movements as large as $\frac{3}{8}$ in. one each side of the null or balance point. The coil and armature type is inherently a small motion pick-up, but is sensitive to motions up to 0.010 in. The output of these systems depend on their design and the power fed into them. For most applications, the coils are kept small and the applied voltage is kept low to adapt them for easy mounting on equipment. The output voltage ranges between 10 millivolts and 4 volts with an allowable current drain between 5 and 20 milliamperes. These values can be built up if higher output is needed. With present availability of sensitive control meters, relays and electronic devices, compactness is more important than signal value.

Usually, the reactors and transformers are excited from a standard 60 cycle source. However, where vibratory motion is encountered higher frequency excitation is needed to eliminate interference between the exciting voltage and the measured signal.

Characteristics of Typical Differential Transformer Circuits

A differential transformer consists of three coils wound on a ceramic tube, which surrounds the movable iron core. The two end or secondary coils are in series and buck one another. The center or primary coil is connected to the power source as shown in Fig. 3.

When the core is centered between the end coils, the coupling between the

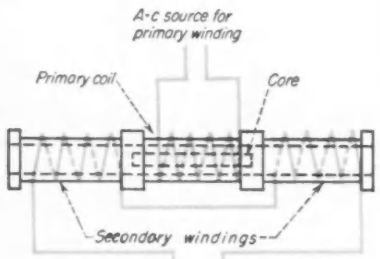
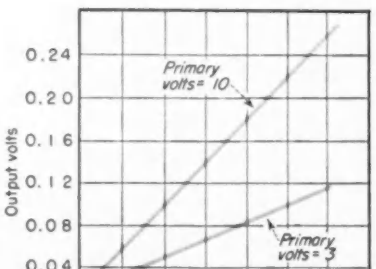


Fig. 3—Typical differential transformer consisting of two secondary windings and one primary winding on a ceramic tube with a movable iron core.

primary and secondary windings is balanced so the induced voltages in the secondary windings balance each other. As the core is moved out of balance, the coupling between one coil and the primary winding increases, while the coupling between primary and other secondary winding decreases. As the secondary windings become unbalanced a voltage appears across their leads; this voltage is linear with respect to the core movement. Two curves are shown in Fig. 4 for different values of input voltage, but still higher voltage can be used in the primary for greater secondary output if the coil windings are made heavier.

The use of two bucking coils in the differential transformer gives a bridge effect where a null point exists, and unbalance is measured rather than a change in current flow. As with the variable reactor element, high resistance type measuring devices should be used to keep the system basically potential and not add variables due to current effects. Movements up to $\pm \frac{3}{8}$ inch are being indicated by these units and still greater movements can be handled by modifying the coil design.

Thus, differential transformers are



Baldwin Locomotive Co., Philadelphia

Fig. 4—Electrical characteristics of differential transformer. Signal magnitude has linear relationship with core motion. The smallest motion that can be detected by a differential transformer circuit depends on the quality of the associated signal generator, amplifier and relays.

well adapted for servo type control and indication. In such applications, two elements are used, one located at the point to be measured and one at the indicating or follow-up point. The two secondary voltages are phased so as to null each other. Any relative movement of one produces an unbalance in the system that causes operation of an indicating system or a directional relay. The indicating unit can be moved by hand to balance the system or shifted by a reversing follow-up motor that is controlled by the relay. When used in this fashion, considerable care must be taken to insure correct phasing of the primaries and secondaries. Another approach is to have the unbalance control vacuum tubes where the tube grid voltage determines plate flow and thence the phase angle of the auxiliary winding on a reversing motor.

All of these motion sensing elements are suitable for dynamic or vibratory work, in which case the output voltage has the same wave form as the mechanical motion that moves the core. Examples of applications are wave form study on an oscilloscope or oscillograph and the indication or the control of the peak amplitudes of vibrating bodies.

When the reactor or transformer core is tied to a vibrating body, the bridge circuits previously described give a signal proportional to core movement. If the inductance of the auxiliary components is kept low, the phase angle is not shifted nor the wave form distorted.

Industrial Application of Variable Reactor Circuits

The commercial application of variable reactors and differential transformers range from the measurement of static and dynamic strain to the measurement of relative motion or displacement.

The sketch Fig. 5 is of a journal bearing test set-up at the Thompson Laboratory of the General Electric Co. The circuit, containing two armature-type variable reactors, measures the shaft motion in the journal due to dynamic lubricating oil film changes. In this application, the coil sections of the cores are mounted diametrically opposite on the shaft, with small air gaps between them and the shaft. The shaft acts as the armature for bore cores. Any shift in the shaft position gives a change in the balance of the two elements.

This same circuit is made up in a package by the Westinghouse Electric Corp. for use as a magnetic strain gage on structural members. The sensitive elements are mounted on a steel plate which in turn can be bolted to the structural member to be tested or monitored. A typical use is on the boom of a crane as shown in Fig. 6. As the load is applied, the boom deflects, and this actuates the sensitive elements which give the operator a visual indication of the load he is lifting and also a signal when the maximum safe load is reached. The same type circuit could be arranged to stop the crane motors should the operator attempt to lift an overload. The pick-up is fully sealed against the weather and is easily attached to the equipment that is to be protected.

The mean static distance between the two vibrating bodies, or the distance between their centers of vibration can be measured automatically by a variable reactor bridge circuit. The circuit is nulled in the static condition and if sufficient time delay is built into the control section, the modulated signals received from each leg cancel without affecting the meter or relay. Any shift in the mean distance, however, will increase one signal and decrease the other, giving an unbalanced indication.

For example, a bridge circuit containing two coils with a single core and rectifiers in the other legs can be used to control spring tension or compression in a fatigue testing machine. The sketch, Fig. 7, shows the machine elements involved. The machine applies two forces to the specimen, one static and one dynamic. The static force is applied by springs, through the vibrating platen, and a constant average spring force must be maintained, irrespective of the amplitude of the dynamic motion. The vibrating platen is driven by a rotating eccentric weight. As soon as the specimen weakens and creeps the load in the springs is affected.

The pick-up circuit senses the magnitude of the signal from each coil and so long as the mean position does not change, these signals are equal. But any shift in the mean position of ± .001 in. or more actuates the control. This control action causes a motor to move the stationary platen so as to restore the original mean distance and again null the pick-up. Thus, spring load is kept constant.

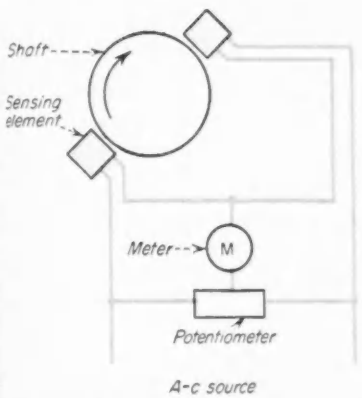


Fig. 5—Variable reactor set-up for journal bearing-oil film test. Any shift in shaft position is indicated and measured.

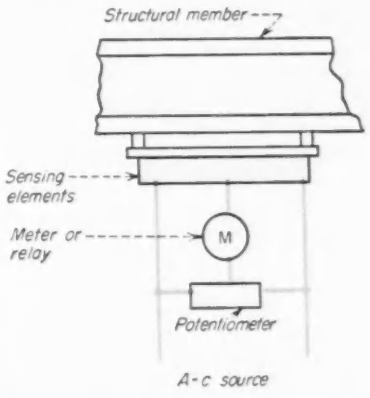


Fig. 6—Variable reactor can be applied to trip a warning circuit should the structural member of a crane be overloaded.

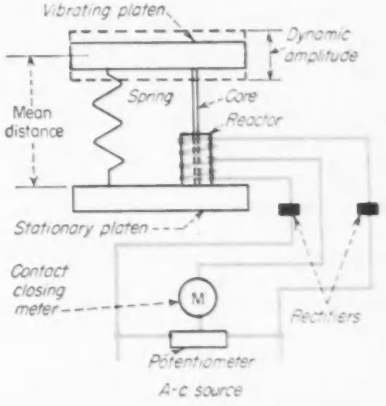


Fig.7—Variable reactor circuit used to control spring load in a Baldwin Locomotive Company fatigue testing machine.

Industrial Applications of Differential Transformer Circuits

Differential transformers are used in many commercial instruments — more so, perhaps, than variable reactors. Variable reactors are usually designed for a particular condition, while differential transformers are stock items that can be adapted to many uses.

One of the latest applications is in a pressure gage. A standard bourdon tube is used to change a pressure impulse into lineal motion. The core of the differential transformer is connected to the end of the tube. The voltage output of the transformer is a direct function of the tube movement. It actuates a voltmeter calibrated in psi. The use of this system eliminates practically all fricitional load on the bourdon tube, and the lineal voltage response gives a unit with high sensitivity and accuracy. In addition sudden pressure drops cannot damage sensitive gear trains as all linkage is electric or magnetic.

As illustrated in Fig. 8, the differential transformer is the sensitive element in a variety of packaged transmitters. Units are available that will respond to weight, temperature, pressure, etc. The transmitters operate in conjunction with a series of control, indicating, and measuring devices that also are packaged, catalog units.

A meter for detecting or measuring the horsepower transmitted by a drive shaft employ a differential transformer. As shown in Fig. 9, the core is mounted on the propeller shaft and the coil is mounted at a point 4 to 6 ft away. Actually a sleeve this long is clamped on the shaft so that the core and coil are together but their relative

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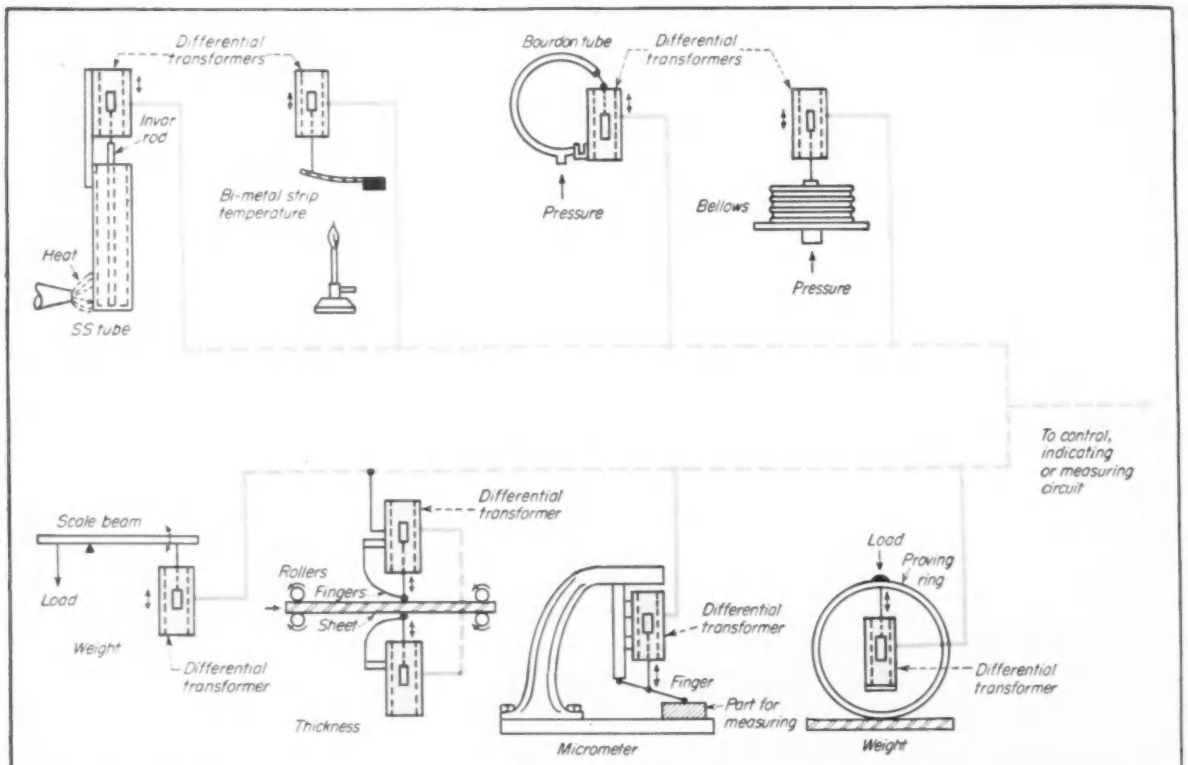
motion reflects the twist in this length of shaft. Under load, the shaft twists proportional to the load in it and the transformer element indicates this twist. The electrical signal is taken off the rotating shaft through slip rings. As the signal is electrical and represents torque, it is quite easy to integrate it with an electric speed signal to give direct horsepower indication, or average this against time to get horsepower or kilowatt hours.

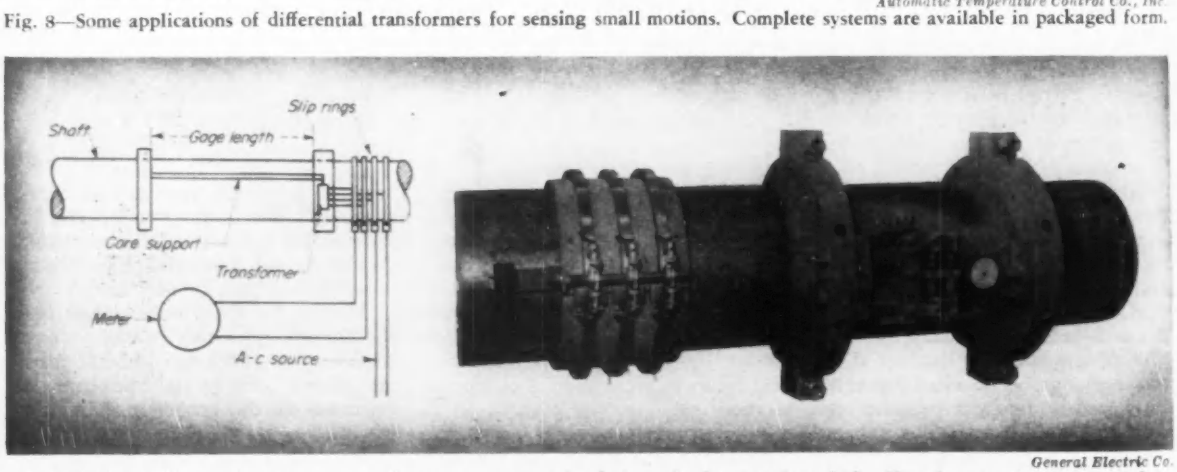
These sensing elements are widely applied to indicate strain in a specimen under static test. The element is clamped to the gage length of the specimen through an amplifying leverage and sends its signal to a control circuit. The control circuit operates a follow-up motor with its own sensing element, similar to the follow-up servo circuit previously described. As the specimen strains and moves its sensitive element the control circuit operates the follow-up motor until both elements are in balance. This type circuit gives a powerful drive to a recording pen without imposing a drag on the pick-up. In addition, the force or stress applied to the specimen is integrated with this strain motion, so that stress-strain records are made directly.

This list of commercial applications shows the versatility of variable reactors and differential transformers for control and measurements. They are suitable for static and dynamic work and, for most applications, require the minimum of auxiliary equipment. Circuits can be set up with few components to give a good, dependable and low cost circuit, and, also experimental circuits can be set up without costly instrument investments.



Automatic Temperature Control Co., Inc.

Fig. 8—Some applications of differential transformers for sensing small motions. Complete systems are available in packaged form.



General Electric Co.

Fig. 9—Differential transformers measure horsepower transmitted through this rotating shaft. Transformer signals are led to indicating circuit through slip rings. Actually, the devices measure twist, which is proportional to torque.

Fig. 1—Top view of a 20 tooth on-center face gear. Note how teeth are trimmed at inner edges.

Face Gear Design Factors

VICTOR FRANCIS and JOSEPH SILVAGI

Rules for determining the maximum practical outside diameter, the minimum practical inside diameter, and the face width of face gears. Data are included for calculating the principal dimensions of on-center face gears of different tooth pressure angles and gear tooth ratios.

THE FACE GEAR is a crown-type bevel gear that meshes at right angles with a conventional involute pinion. The pinion may be either spur or helical. The gears may have right-angle intersecting shafts forming a bevel gear set; or they may have right-angle nonintersecting shafts forming an off-set or hypoid arrangement.

Face gears have been commercially manufactured for many years. They have been used in textile machinery, truck engine governor drives, power mower transmissions, and gear cutting machinery, but the use of face gears has not been as widespread as their practicability warrants.

The pinion, being a conventional spur or helical gear, can be produced on a hobbing machine or on a gear shaper. The same shaper cutter can be used to produce both the pinion and the face gear.

On a conventional bevel gear of octoid tooth form, the face width theoretically can be increased outward indefinitely. Actually, the tool and the machine are the limiting factors. The pitch merely increases in proportion to the diameter, the pressure angle at the center of the tooth remains constant. Increasing the width of the face towards the apex of the gear is limited by the thickness of the tool and by side trimming of the teeth at the small end, which results from the tool being at the gear root angle and not at the theoretical cone angle.

On the face gear, however, the operating pressure angle increases towards the outside diameter, Fig. 1. The depth of the tooth remains constant. The maximum usable outside diameter is the diameter or a slightly larger diameter at which the teeth become pointed. The limiting inside diameter is the point where tooth trimming occurs, which is always outside the diameter where the operating pressure angle becomes zero. With a small number of teeth and a low gear ratio, it is possible to have the minor trimming diameter equal the pointed outside diameter; such a condition would leave no usable face width. The gear shown in Fig. 1 has a face width of one inch; if the trimmed portion on the inside and the pointed portion on the outside were removed, an effective face width of one-third of an inch would remain.

The physical appearance of face

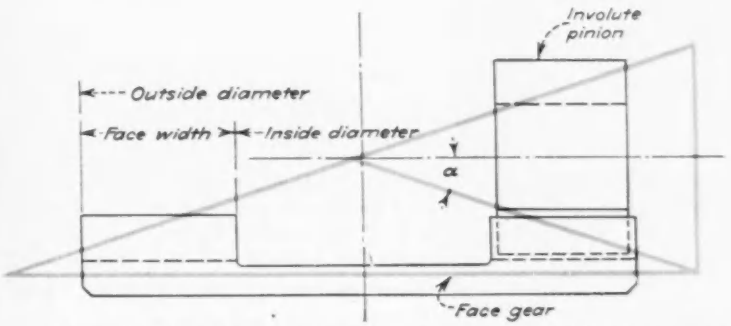


Fig. 2—Rolling pitch bodies for a spur gear and on-center face gear are cones.

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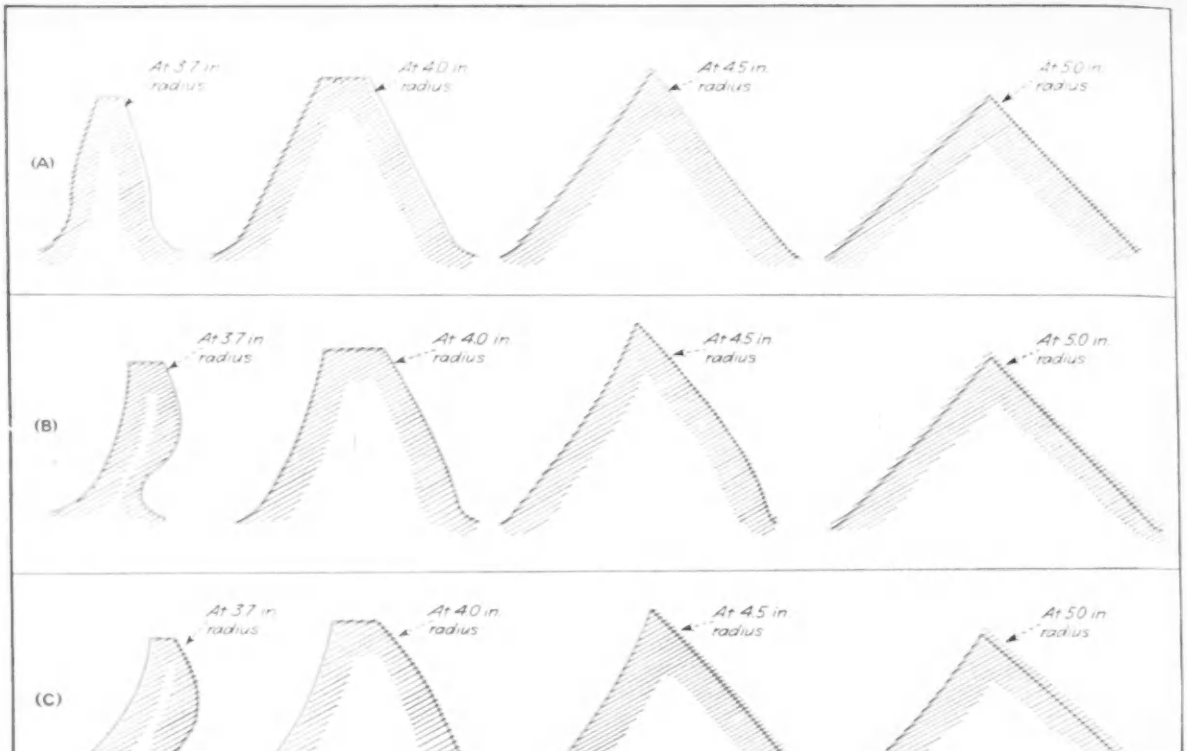
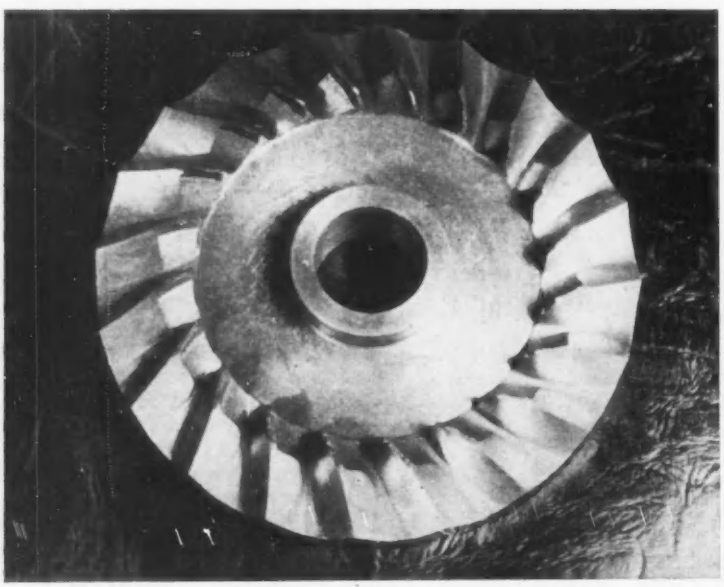


Fig. 4—Calculated profiles for a 1 diametral pitch, 8 tooth gear, taken at 3.7, 4.0, 4.5 and 5 in. radii. (A) On-center gear. (B) Offset gear. (C) Helical gear. Profiles do not show the effects of trimming.

Fig. 3—Top view of offset face gear. Interference of the cutting tool produced the trimming that can be seen on the inner or small end of the teeth.

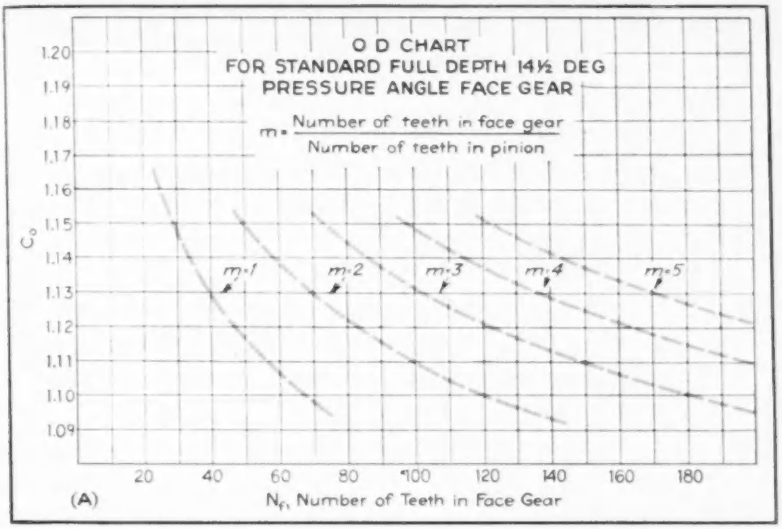


gears, at first glance, resembles that of crown gears, and does not suggest that the pitch skeletons are cones. The pinion is made as a true cylindrical involute gear. The two gears when meshed with intersecting axes, Fig. 2, act as bevel gears and do have cones as their pitch surfaces or rolling bodies.

Since the operating pressure angle changes from the minor to the major diameters and the working depth of the two gears is constant, the instantaneous line of tooth contact is a diagonally curved line moving along the tooth as the face gear and the pinion roll together.

For ease of computation when designing the gears, it is sometimes assumed that the face gear tooth surface is composed of approximately straight lines. The surface, however, does not contain any theoretically straight lines. The line elements composing the tooth surface can be concave, convex, and even both, depending on the numbers of teeth and the gear ratio.

With pinion offset or helical conditions, the profile variations are more pronounced. In Fig. 3, notice how the teeth become trimmed at the small end as a result of radial crowding and how the teeth become pointed at the outside diameter because of the pressure angle increasing with increas-



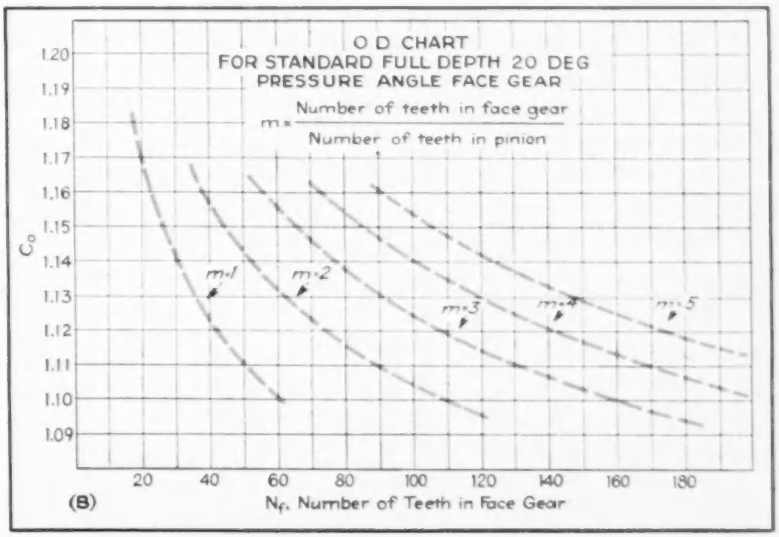
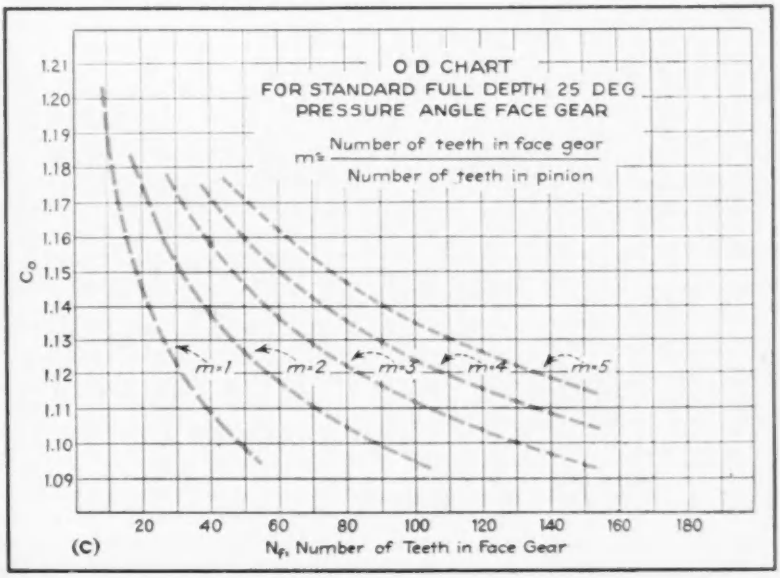


Fig. 5—Charts for obtaining the factor C_o used in the formula for computing maximum usable outside diameter of on-center face gears. (A) Values for standard full depth 14½ deg pressure angle. (B) Values for standard full depth 20 deg pressure angle. (C) Values for standard 25 deg pressure angle.



ing diameters. In Fig. 4 are shown profiles of the tooth forms at different diameters of the face gear for on-center, hypoid, and helical types. These profiles are for an extremely exaggerated case of an eight tooth face gear meshing with an eight tooth, 30 deg pressure angle pinion. This condition was chosen to show more clearly the curvatures of the profiles that are obtained. The effects of trimming or undercutting have been omitted in drawing these profiles.

In actual practice the gear ratio is seldom as low as 1.0, and the number of teeth in the face gear would never be as small as eight. A five diametral pitch set with 20 teeth in the pinion and 20 teeth in the gear would have about 0.005 in. concavity of the profile for an on-center type.

The face width of face gears is limited by the teeth becoming pointed at the outside diameter and trimmed or undercut at the inside diameter.

Profile curvatures are caused by numerous factors and the exact determination of the maximum outside diameter is mathematically difficult. To facilitate the design of spur, on-center face gears, charts for assisting the designer in determining the maximum outside diameter at which the face gear teeth become pointed are given in Fig. 5 for standard full depth 14½, 20, and 25 deg pressure angle face gears. In most cases, the outside diameter will be designed smaller than this maximum diameter. Some gears, however, will have to be designed with a slightly larger outside diameter to obtain sufficient face width to carry the desired load. The tooth contact ratio at this increased diameter will still be greater than one but a large amount

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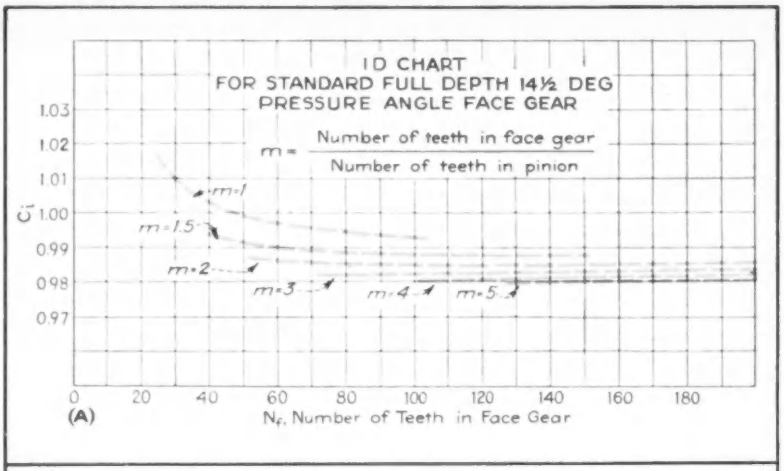

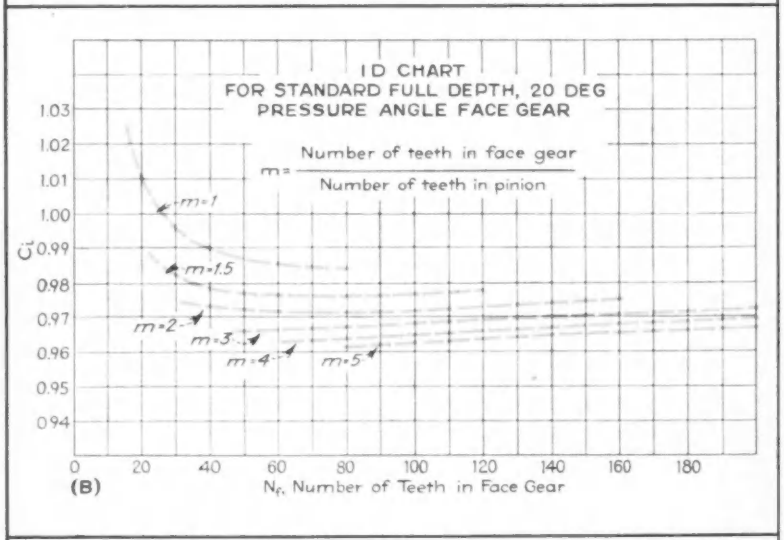

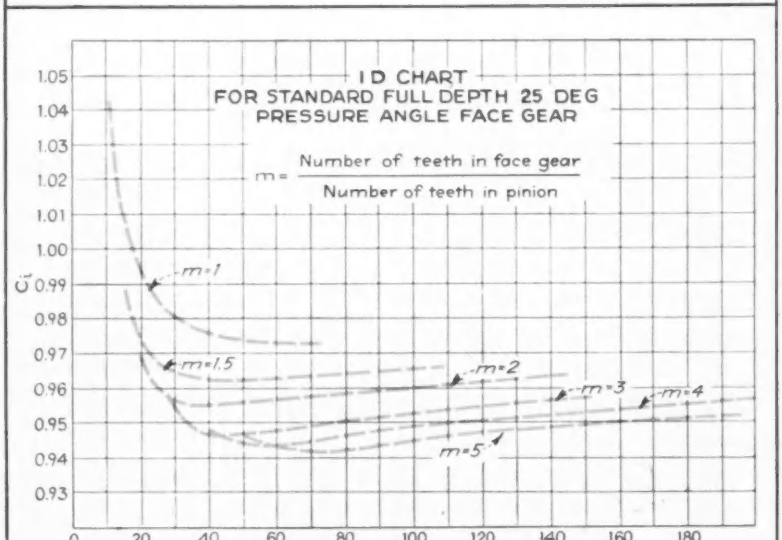

Fig. 6—Charts for obtaining the factor C_i used in the formula for computing the minimum usable inside diameter of on-center face gears. (A) Values for standard full depth 14½ deg pressure angle. (B) Values for standard full depth 20 deg pressure angle. (C) Values for standard full depth 25 deg pressure angle.

of relative sliding will occur. Thus, if necessary, it is permissible to have pointed teeth for a small portion of the face width.

N_f = number of teeth in the face gear.
N_p = number of teeth in the pinion.
m = N_f / N_p.
D_{fg} = pitch diameter of the face gear and is equal to m times the pitch diameter of the pinion, in.
C_o = equals a constant from chart, Fig. 5, obtained from the intersection of the N_f ordinate with ratio m curve and reading horizontally to the left.

the pointed diameter is

Pointed diameter = $C_o D_{fg}$, in.

For determining the Minor Diameter where trimming occurs, the charts given in Fig. 6 will be found useful. They are based upon the establishment of the face gear pitch plane, Fig. 7, as the limit for the height of the trimmed portion.

To use the I D Charts, locate the intersection of N_f with the m ratio curve, and read across horizontally to obtain a value of C_i. Then

Minor dia of face gear = $C_i D_{fg}$

EXAMPLE 1. Find the minimum inside dia, maximum outside dia, and the face width of a 40 tooth face gear driven by a 20 tooth full depth standard tooth thickness, 2 diametral pitch, 20 deg pressure angle pinion.

$m = 40/20 = 2.0$
$D_{fg} = (20/2) \times 2 = 20$

SOLUTION: Use chart in Fig. 6 (*B*). The intersection of the 40 tooth face gear ordinate N_f crosses the m curve 2 at the point where C_i has a value of 0.972.

Hence, the minimum ID is

$C_i D_{fg} = 0.972 \times 20 = 19.44$ in., approximately 19 7/16 in.

This dimension is the minimum diameter that may be used, since the chart is based on a diameter where trimming occurs at the middle of the tooth height. A slight amount of trimming may occur above or below the middle as shown in Fig. 7. This small amount of trimming, however, will not be detrimental to the quiet running qualities of the gears and allows the use of the maximum amount of profile.

To find the maximum outside diameter of the face gear, use the OD Chart Fig. 5(*B*). The intersection of the 40 tooth face gear ordinate crosses the m curve 2, at the point where C_o equals 1.159. Hence, the maximum OD is

$C_o D_{fg} = 1.59 \times 20 = 23.18$ in., approximately 23 3/16 in.
Face width = (23 3/16 − 19 7/16)/2 = 1 7/8 in.

EXAMPLE 2. Find the minimum inside diameter, maximum outside diameter and the face width of a 126 tooth face

gear driven by a 36 tooth full depth standard tooth thickness, 10 diametral pitch, 14½ degree angle pinion.

$m = 126/36 = 3.5$
$D_{fg} = (36/10) \times 3.5 = 12.60$

SOLUTION: From chart Fig. 6(*A*)

$C_i = 0.981$

Then

$ID = C_i D_{fg} = 0.981 \times 12.60 = 12.36$ in., approximately 12 3/8 in.

From chart Fig. 5(*A*)

$C_o = 1.129$

Then

$OD = C_o D_{fg} = 1.129 \times 12.6 = 14.23$ in., approximately 14¼ in.

Face width = $(14\frac{1}{4} - 12\ 3/8)/2 = 15/16$ in.

If the face width as computed with chart values is too large and must be reduced, most of the un-needed face should be removed from the outer diameter and a smaller amount from the inner diameter, since small pressure angles transmit power more effectively than do large pressure angles.

On parallel axis gear sets, when undercutting would occur in a pinion of

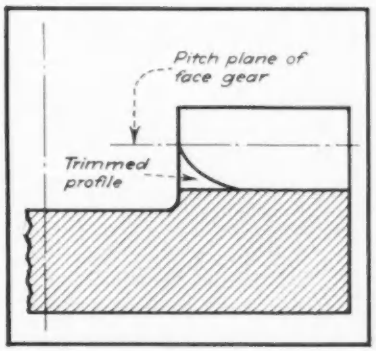

Fig. 7—Intersection of trimmed profile with pitch plane of face gear.

standard tooth form, the common method of avoiding the undercut is to make the pinion oversize. This solution, in effect, transforms the pinion into one of a slightly larger diametral pitch and a larger pressure angle. By operating the modified pinion with a gear made proportionally undersize, the original lower and superior operating pressure angles can be maintained.

The operating pressure angle of a face gear set, however, varies from a minimum value at the inside diameter to a maximum value at the outside diameter of the face gear. Because of this change of pressure angle the advantage of making a pinion oversize to avoid undercutting is lost. The better practice is to make the set with a higher basic pressure angle. Values of C_o and C_i for pressure angles lying between those given on the charts can be accurately interpolated from the chart values.

EXAMPLE 3. Find the value of C_o for a 54 tooth face gear driven by an 18 tooth full depth standard tooth thickness 22 deg pressure angle pinion?

$m = 54/18 = 3.0$

SOLUTION: From charts Figs. 5(*A*) and (*B*).

For 20 deg, $C_o = 1.164$
For 25 deg, $C_o = 1.144$
$\Delta C_o = 1.164 - 1.144 = 0.020$
$\Delta\phi = 25 - 20 = 5$ deg

For 22 deg pressure angle

$C_o = 1.164 - (0.020 \times 2/5) = 1.1566$

When compared with the conventional type of bevel gear, face gears have the following advantages:

1. The face gear can be checked for accuracy of tooth profile on a checking fixture.

2. The pinion of a face gear set can be adjusted axially at assembly without affecting contact or backlash. Thus, only one assembly distance has to be maintained accurately as compared with two assembly distances for conventional bevel gears. On the condition that its face remains in contact with the face gear, the pinion may be given any amount of axial movement. There is no axial thrust on the pinion bearings of an on-center gear set.

3. Pins or balls can be used for checking the size of face gears and the dimension can be computed when designing the gears.

4. The generation is positive with no trial and error settings required to obtain the conjugate profile.

5. Hypoid, or off-center face gears, are produced on the same machine and with the same cutter that are used to generate on-center face gears and the cylindrical involute pinions. Furthermore, the cost of the product is not increased by changing from on-center to hypoid face gears.

The disadvantages of face gears as compared with the conventional bevel gear are:

1. In some designs, the face width of face gears is limited by pointed teeth and trimming.

2. Shaper cutters for face gears are usually less versatile than the cutter blades used to produce conventional bevel gears.

Face gears are made by a continuous generating-shaping process on a Fellows Gear Shaper or similar type machine, Fig. 8, using a special fixture designed to put the face gear axis at right angles to the pinion axis. The pinion-type cutter is a duplicate of the mating pinion. If a twenty tooth pinion is to mesh with a sixty-eight tooth face gear, the shaper cutter for the face gear should also have twenty teeth.

In practice, the cutter is made somewhat larger in diameter and possibly in number of teeth in order to use standard cutters, to obtain more latitude in assembly, or to achieve good production with the larger cutters. Loss of contact and profile modification occurs with this practice, depending on how much the cutter deviates from the mating pinion.

To produce optimum running face gears, a cutter with the same number of teeth as the pinion should be used and should be slightly larger in diameter. This condition must prevail throughout the life of the cutter to prevent binding of the pinion with the face gear at assembly. A side trimming attachment can be used on the generator to compensate for thinning the cutter tooth as it is reground. A cutter with a smaller number of teeth than the pinion should never be used.

The relative number of teeth determine the permissible variation from the ideal number of teeth that the cutter may have. For instance, if a twenty tooth pinion is to drive a twenty-four

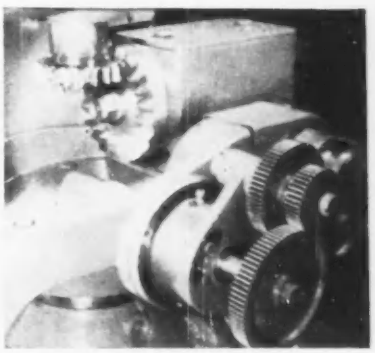

Fig. 8—Shaping a 20 tooth on-center face gear with a 20 tooth, 20 deg cutter.

tooth face gear, the cutter should have twenty teeth to maintain good conjugate action. But if a twenty tooth pinion is to drive a hundred tooth face gear, the number of teeth in the cutter could vary from twenty to twenty-five, depending on the degree of quietness, cutter life, and production rate desired.

ACKNOWLEDGMENT: Photographs used to illustrate this article have been obtained through the courtesy of Atlas Gear Company.

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Benefits Derived From Use of Standards

1. Convenient and dependable service for the customer at lower cost.

2. Reduced manufacturing costs. When numerous companies use the same parts, they can be manufactured in large quantities with uniformity of output, thus contributing to economies in production.

3. Reduced cost of carrying stocks of materials because fewer parts are carried.

4. Reduced cost of instruction of new employees because there are fewer items with which to become familiar.

5. Reduced accounting cost since there are fewer types and sizes of materials needed.

6. Minimized engineering and operating problems that result from intercommunication between widely divergent systems.

7. Makes available large supplies of materials and labor in emergencies.

8. Facilitates development work; since improvement in, or development of, a new article should include the maximum utilization of existing parts or units.

9. Helps to stop practices that are merely the results of accident or tradition and that impede development

10. Enables more thought and energy to be given to more efficient and economical designs.

11. Decreases variances in drafting practice that often cause mistakes, setbacks, waste and high cost.

12. Reduces supervision since personnel do not need step-by-step guidance.

Standards Programs and

Basic considerations that influence the scope and achievement of objectives of standardization programs and the selection of administrative personnel. Steps in a practical operating procedure for initiating and adopting standards. Scope of standards programs, organization structure, and type of approach for efficient operation.

GEORGE E. ROWBOTHAM
Standards Engineer Consultant

UNDER MODERN SCIENTIFIC MANAGEMENT, a standard is a carefully thought out method of performing a function or operation. Most frequently it is a specification covering an implement, some article of stores, or a product. The standard method of doing anything is simply the best method that can be devised at the time the standard is drawn. Based on current knowledge, it defines a practice or specifies an item that best satisfies current conditions.

Standardization, the process of setting up standards, has been defined in a number of ways. While phraseology differs widely, the basic concept underlying the terms is definitely established. Fundamentally, standardization is a way of thinking. The idea of using the same parts, materials, or practices wherever possible to reduce costs is simply a matter of common sense.

Simplification is a policy of management. The objective is to conduct all activities and functions of an enterprise in the simplest manner consistent with any given purpose. It is the reduction in the use of, or production of, the number of different types, grades, sizes, or kinds of items so that manufacture can be concentrated on fewer products. Simplification generally is carried out along with, or directly preceding, standardization.

Whereas simplification reduces the variety of items, standardization insures the uniformity of the items selected for manufacture.

Standardization is possible even though the final product cannot be

Typical Contents of an Engineering Standards Manual

BOOK I

SECTION A—DRAFTING PRACTICE

Drawing Mediums
Drafting Technique
Drawing Forms
Part Numbers
Line Conventions
Sectioning
Lettering
Symbols
Projection and Descriptive Geometry
Layout Practice
Dimensioning
Decimal Dimensioning
Limits and Tolerances
Notes
Drawing Revisions
Checking Practice
Drawing Reproduction

SECTION B—MECHANICAL DESIGN

Spring Design
Gear Design
Splines and Serrations
Screw Threads
Pipe Threads
Bearing Application
Boss Proportions
Clutch Design
Brake Design
Cam Design

SECTION C—PRODUCT DESIGN

Technical data and design factors that are peculiar to the product of the company. Acceptable clearances, allowable working stresses, strength formulas for parts commonly used, methods of lubrication, functional requirements, tightening torque values for bolts, nuts, and screws.

SECTION D—ELECTRICAL PRACTICE

Wiring Diagrams
Electrical Symbols

SECTION E—MANUFACTURING CONSIDERATIONS

Stampings
Castings
Die Castings
Powdered Metals
Forgings
Plastics
Rubber
Machine Operations
Surface Roughness
Plating

SECTION F—METALLURGICAL CONSIDERATIONS

Ferrous Metallurgy
Nonferrous Metallurgy
Heat-Treatment
Hardness Specifications

SECTION G—ASSEMBLY CONSIDERATIONS

Fastening Methods
Bolts and Nuts
Screws
Locking Devices
Riveting
Welding
Brazing
Soldering
Assembly Operations
Tube Fittings
Wrench Clearances

SECTION H—LEGAL CONSIDERATIONS

Patent Procedure
Identification and Trade Marks

SECTION Z—TABLES

Standard Sizes and Tolerances
Useful Formulas and Constants

BOOK II—SPECIFICATIONS

Screw Threads—Unified and American
Pipe Threads—Dryseal
Splines—Involute
Serrations
Materials
Finishes

BOOK III—STANDARD PARTS

Catalog of standard parts such as screws, fittings, bolts, nuts, washers, etc.

BOOK IV—ORGANIZATION AND PROCEDURE

ORGANIZATION AND POLICY

Responsibilities and Jurisdictions of Personnel
Organization Chart
Regulations
Policy

PROCEDURE

Drawing Releases
Change Orders and Notices
Stop Orders
Cost-Analysis Investigations
Overtime
Planning and Scheduling
Stenographic Facilities
Charge-out System for Blueprints
Accounting
Catalogs and Data

Procedure

completely standardized. Often with slight modification in design, component parts of machines, apparatus or other equipment such as locks, doors, hinges, compartments, screws and bolts can be standardized with advantage to the company and customer.

Market research and scientific cost accounting are the bases upon which rest the decision as to the degree to which standardized output can be profitably pushed.

Many companies recognize that more types and styles of products are being offered than are deemed practical from a production standpoint. But, in recognition of the rather peculiar and distinct nature of some fields of business, they appreciate that competition plays a prominent part in any program aimed at suppression of a widely diversified line.

These companies discovered through experience that customers will place their orders elsewhere when the particular style desired is not offered. By not filling orders for items that are not standard, manufacturers naturally fear that the customer will give the order to a competitor; and as a result, give him all future orders, including those for items termed standard. Before attempting any product standardization, therefore, it is recommended that a survey be conducted by the company among its customers to ascertain their style preferences.

An inherent hazard in large scale standardization programs is the danger of prompting or encouraging companies with large operating capacities to enter the field as competitors. For instance, participation in any large scale standardization program by concerns making the same types of product might limit style lines. Limiting styles increases the benefits that accrue from the quantity production of a few items. If the business consequently appealed to large manufacturers who were willing and able to invest money in tools, there would be the threat of eventually squeezing the small companies out of the field.

The successful administration of a standardization program depends largely upon: (1) The clear definition of the duties and responsibilities of the individuals assigned to perform such work, and (2) an understanding of the functional relationship of the standardization personnel to the engineering and plant personnel. Definite distinctions, of course, are neeeded to reduce the possibilities of misunderstandings or misinterpretations, to avoid personal friction and to prevent the overlapping of jurisdictions. Definitions of duties and responsibilities should anticipate potential points of conflict and clarify them in advance of their occurrence.

In the development of a standards program, the first step is the careful investigation of the character and quali-

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fications of possible candidates to conduct the program. The selection of the standards engineer is extremely important. He is the dynamic force in the development and operation of the program.

The competent standards engineer should have a sound engineering background and a thorough knowledge of manufacturing methods. He should be familiar with engineering design practice, and enthusiastic in promoting the advantages of standardization.

He should possess resourcefulness in developing ways to accomplish the desired result. Often there is active opposition to standardization. In such an event, the standards engineer needs the courage and disposition to persevere in spite of difficulties discouragement, or indifference.

He should have the type of mind that integrates, condenses, and simplifies facts rather than for expanding, ramifying, complicating, and disintegrating them.

He must have a clear understanding of the cooperative principles associated with standardization work, and be able to gain the confidence and cooperation of his associates in carrying on his work effectively. He must have the ability to command respect through his evident competence, and to get along with people because they admire him as an individual.

The next step in the formulation of a standards program is the definition and delegation of the duties and responsibilities of the standards engineer. Publication of these definitions and delegations serves to inform the various operating units in the company of the formulation of a standards program. It emphasizes also the necessity for plant wide cooperation.

Next, the standards organization structure and type of approach for efficient operation must be determined. The size of the company, obviously will determine the size of the standards department. In a small company, an adequate program can be carried on by one man, and sometimes by one man who devotes only part of his time to the work. Larger concerns, with widespread operating areas and subsidiary activities to be correlated into a master standards program, may require the full time services of several engineers.

Regardless of the size or nature of the company's business, every phase of the program should be aimed at the improvement and simplification of work and at curbing costs.

Scope of Standards Program

The word scope as used in this discussion means the delineation of jurisdiction or pertinency, not a predetermined itemized table of contents. It is not practical, or even desirable, to attempt to forecast the scope of the standards program at the early stage of development. At that time the scope should be unrestricted, subject to later decision as the project develops.

In the beginning, the accepted policy in regard to scope should be: That it is the prerogative of the standards engineer to delineate such scope, that all competent employees can influence his decision by comment, and that in the final analysis his decision is always subject to confirming action by the chief engineer, which in effect, represents the viewpoint of management.

Often it is advisable, however, to outline a table of contents. Such a table of content is not intended to forecast the scope of the standards program, but is primarily a recommendation for arrangement of material, technical data, and general information, required or useful, for the promulgation of standard practice.

The standards engineer should persuade his company to form a standards committee. This committee should not be burdened with detailed assignments, nor should its members be expected to attend lengthy or numerous meetings. Most of the work may be handled through a letter ballot.

A democratic procedure is the only sure way to obtain absolute enforcement of standardization. With committee backing, enforcement will not be a problem. When every key person directly affected by the standards has a voice in the formulation of the standards, he will readily accept them as his own creation. It should be remembered that many problems and difficulties are the common property of the entire company and can be surmounted only by group action. In addition, inclusion of all interested persons in a standardization committee is a most effective selling method.

The steps in a practical operating procedure for initiating and adopting standards are:

1. After compiling a draft of a proposed standard, the standards engineer, with the approval of the chief engineer, submits directly to each member of the standards committee a copy of the draft and requests comments in writing within a specified reasonable time limit.

2. After receiving comments from the committee, the standards engineer revises the standard as required and resubmits it to the committee for final approval.

3. When it is not practicable to settle controversial details by balloting, it may be desirable to hold a committee meeting for those members who are particularly interested in the standard in question. Perhaps all members of the committee will not share a common interest in all standards. Each committee member, however, should be invited to comment on all standards and attend all standards meetings. With such procedure, each individual member can decide whether or not the standard affects his work or holds his interest.

4. The standards engineer generally should be the chairman at all standards committee meetings.

5. After approval of the standards committee is obtained, the standards engineer releases the standard.

This procedure may be modified slightly to suit the particular requirements of the company involved. For instance, in a large organization where numerous committees operate, specialists may be responsible for standards and be committee chairman, in such events, the standards engineer might act as a secretary.

The standards engineer should act on request of others for new standards or revisions of old ones; and if necessary, initiate desirable standards projects. Constructive comments and criticism should be encouraged. Any employee should feel free to submit a written request for a standard or a revision. But employees should understand that all projects are under control of the standards engineer, and that he will determine the feasibility of the request through consultation with the chief engineer, the sender, and other departments affected.

Divergent views of different departments on existing standards should be coordinated and reconciled by the standards engineer. Fundamentally, standards work must sell itself by its own merit and by demonstrating that wide use of standards and good design are entirely compatible. Men engaged in standardization work should constantly remember that cooperation is the basic element in standardization, and that it involves the pooling of widely varied knowledge and practical experience of able specialists.

Constant surveillance over current practice within the company should be maintained by the standards engineer so that he can:

1. Revise existing standards in light of new developments.

2. Check unjustified departures from standards.

3. Avoid over-expansion of product line when needs can be filled satisfactorily from existing line.

4. Insure proper control of standards. All drawings, both production and experimental, should be screened

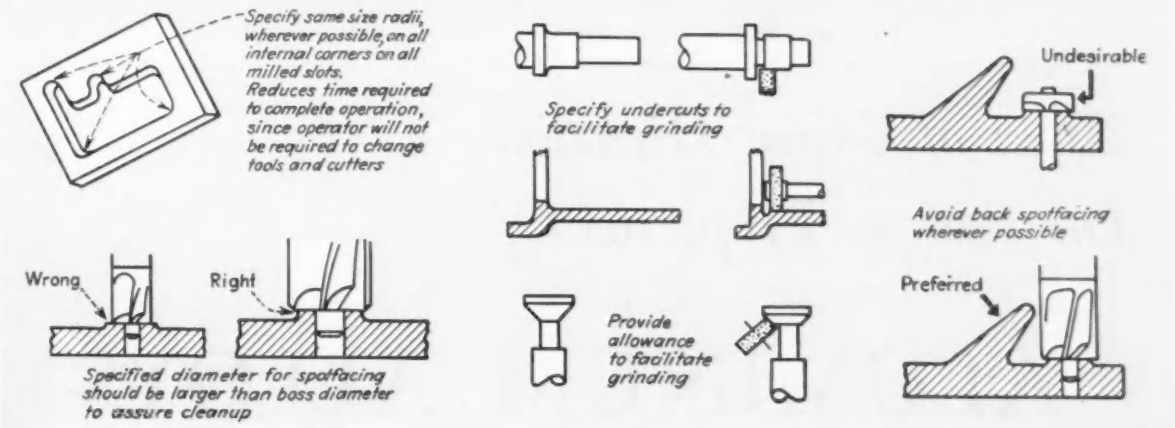
Specify same size radii, wherever possible, on all internal corners on all milled slots. Reduces time required to complete operation, since operator will not be required to change tools and cutters
Specify undercuts to facilitate grinding
Undesirable
Avoid back spotfacing wherever possible
Wrong
Right
Specified diameter for spotfacing should be larger than boss diameter to assure cleanup
Provide allowance to facilitate grinding
Preferred

Fig. 1—Typical information included in a standard to remind engineers and draftsmen of design details that facilitate machining.

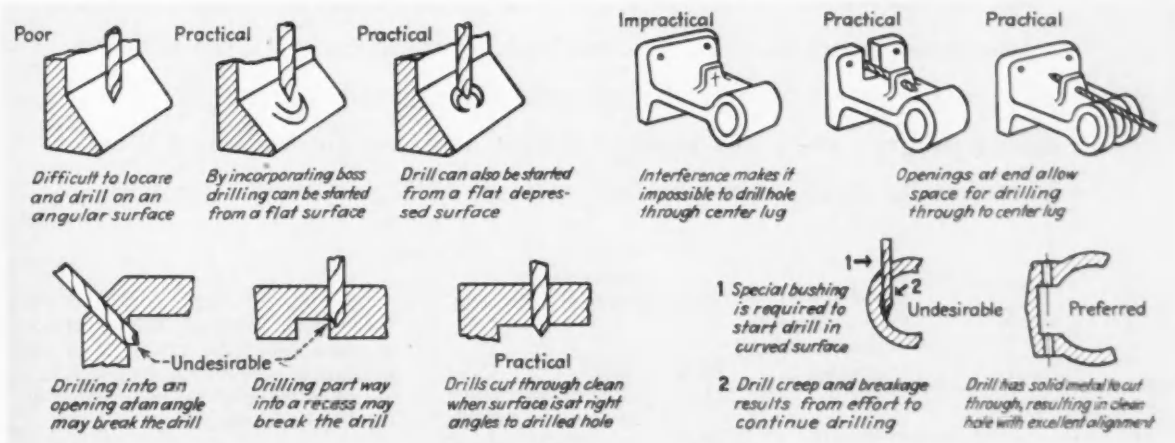
Poor
Practical
Practical
Difficult to locate and drill on an angular surface
By incorporating boss drilling can be started from a flat surface
Drill can also be started from a flat depressed surface
Impractical
Practical
Practical
Interference makes it impossible to drill hole through center lug
Openings at end allow space for drilling through to center lug
Undesirable
Drilling into an opening at an angle may break the drill
Drilling part way into a recess may break the drill
Practical
Drills cut through clean when surface is at right angles to drilled hole
1 Special bushing is required to start drill in curved surface
2 Drill creep and breakage results from effort to continue drilling
Undesirable
Preferred
Drill has solid metal to cut through, resulting in clean hole with excellent alignment

Fig. 2—Design details that should be considered to facilitate drilling operations, to avoid tool breakage, and to improve quality.

by the standards engineer before being released. Likewise, it may be advantageous that he should screen bills of material on both new and old sales orders as a means of investigating the use of parts as a step toward establishing anticipated usage or need for retiring an inactive part.

The standards engineer should encourage company participation in standardizing activities of the industry, trade associations, technical societies, and national standards organizations. He should emphasize the importance of his company keeping abreast of national and industrial developments. He should keep the company informed on new or proposed standards of other companies and standards groups. The objective being to appraise his company of the latest activity and progress in the standards fields.

Much of the work of engineering standardization is the development of a detailed record, in permanent form, of standard practice instructions covering drafting practice, mechanical design, product design, electrical practice, manufacturing considerations, and assembly considerations. These instructions are usually published in an engineering standards manual. The table on page 123 gives the typical contents of such manual.

Lack of definite and clear understanding caused by variances in drafting practice often results in delays, mistakes, setbacks, waste and high cost.

Standards such as are shown in Figs. 1 and 2 often serve as reminders. They record information known to many engineers and draftsmen. Yet a review of the alteration blocks on many drawings will indicate that what appears to be obvious is frequently overlooked. Standards should provide information that can be easily followed with reasonable judgment, and should present simple logical design that can be produced at low cost.

Even though standards may include much technical data found in reference books, experience proves that standard data sheets must be prepared especially for the work of the particular engineering department that is to use the standards manual.

Engineering standardization also encompasses engineering procedure analysis and engineering work simplification. The term "work simplification" is intended to mean here an organized critical review and inspection of operations. Its objective is to avoid all non-essential work, and to improve the manner in which essential work is to be performed. Method work, or procedure analysis, is essentially the thoughtful and comprehensive analysis of an operation.

Unlike the work of the mathematician that is completed when the problem is solved, the work of the standards engineer has just begun when he has found the solution to a problem.

Before his work can be of any value to his associates, others must know about it and be able to use it. He must be able, therefore, to write clearly about his work. For the benefit of inexperienced personnel, all text material should be in simple language.

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Effect of Grain Direction On Fatigue Properties Of

ALUMINUM ALLOYS

Since the orientation of test specimens with respect to direction of working is known to have an effect on static mechanical properties, it is often assumed to have a similar effect on dynamic properties. Results of an intensive fatigue testing program show this assumption to be erroneous for aluminum alloys. These results should influence design trends in highly stressed structures.

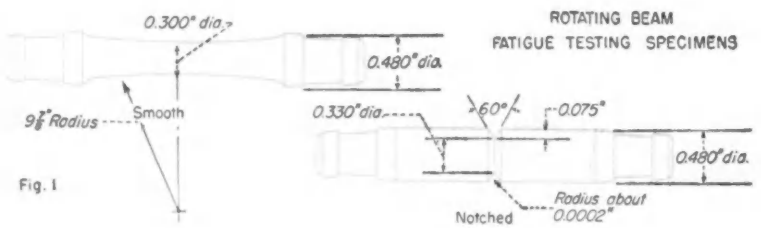

Fig. 1

R. L. TEMPLIN
Asst. Director of Research and Chief Engineer of Tests

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Chief, Engineering Design Division

Aluminum Research Laboratories, Aluminum Company of America

INCREASES in allowable static stresses, made possible by improved tensile properties of aluminum alloys, have led to the erroneous assumption that allowable fatigue stresses could be increased in the same proportion. This practice often results in lower margins of safety against fatigue failures, particularly in the presence of stress raisers. While it is true that designs can and should take advantage of the improved static properties of aluminum alloys, it is felt that greatly increased fatigue loads should be accommodated through design improvements.

The erroneous assumption — that some static property of a metal is a reliable index of its fatigue strength — is too often extended to include property differences caused by different orientations with respect to the direction of working.

It is generally known that static mechanical properties of metal products vary with the major direction of working in such processes as rolling, forging, drawing and extrusion. Tensile strength, yield strength and ductility values, obtained in specimens taken parallel and normal to the direction of working, are different. The magnitudes of these differences vary with the size of product, type of working, heat treatment, and the metal or alloy used.

Ductility values, determined from elongation or reduction of area measurements made in the shorter transverse direction* on high strength aluminum rolled plate, forgings and extrusions, are generally lower than values obtained from specimens in the longitudinal direction. The occurrence of these low static values raises the question of whether low fatigue values would be expected for the material in the transverse direction.

** In a bar of rectangular cross section, the width and thickness are respectively the longer transverse and shorter transverse directions.*

FATIGUE TEST RESULTS

Many results of fatigue tests of high strength aluminum alloy products, made over an extended period, have been published (see References). The results of over a thousand rotating beam fatigue tests performed over the last decade in the research laboratories of the authors' company, are presented in this article.

The static tensile properties of 14S, 24S and 75S alloy semi-finished products are shown in Table I; 24S alloy is not commercially available in the form of forgings. Whenever specimens could be obtained, static properties are given for two or three principal directions, with respect to the major working direction.

The fatigue data were obtained on an R. R. Moore type of fatigue machine, using both a Moore type of plain specimen and a notched type of specimen (see Fig. 1). The notched specimen is of empirical design and has a very sharp notch. Stresses indicated for the notch fatigue tests were computed as though the specimen were smooth and had a diameter equal

Table I—Static Tensile Properties of Products Tested in Fatigue (See Figs. 2-5)

Alloy and Temper	Product	Size, in.	Longitudinal				Longer Transverse				Shorter Transverse			
			Tensile Strength, psi	Yield Strength, psi*	Elong. in 2 in., %	Red. of Area, %	Tensile Strength, psi	Yield Strength, psi*	Elong. in 2 in., %	Red. of Area, %	Tensile Strength, psi	Yield Strength, psi*	Elong. in 2 in., %	Red. of Area, %
14S–T4	Rod	¾ dia	66,800	41,000	27.5	40								
	Forging	⅞ dia	64,000	37,300	22.3	27								
		1x7	64,700	41,800	18.4	—	64,000	39,700	18.4	—				
		1x7	74,200	51,300	16.0	—	68,200	44,200	14.0	—				
	Extrusion	2⅜x2½	75,900	55,300	16.0	23								
14S–T6	Rod	¾ dia	72,100	63,800	14.0	34								
		¾ dia	71,000	63,500	13.5	30								
		¾ dia	71,400	63,800	14.5	29								
		3½ dia	72,100	66,000	10.9	—								
	Plate	¾	67,700	58,800	12.0	21	66,600	58,100	10.5	18				
	Forging	⅞ dia	70,000	62,200	13.0	25								
		1x7	68,700	61,900	10.0	—	71,400	65,100	8.0	—				
		1x7	75,000	68,700	8.0	—	72,600	66,900	6.0	—				
		1½x5	69,700	61,800	11.2	21	70,400	63,100	7.2	11				
		5x12	64,000	55,300	7.9	13	64,900	55,500	8.1	13†	62,300	58,200	2.0	4
		Impeller	70,500	61,100	10.4	—								
	Extrusion	⅝x4	67,600	61,000	11.7	—	64,200	56,500	10.8	—				
		2¼x3½	69,600	61,500	9.7	—	65,000	58,200	6.0	—				
		2⅜x2½	75,000	67,500	10.0	23								
		3½ dia	75,800	68,200	9.6	—	66,400	60,300	5.2	—†				
		3⅝x6	71,000	63,200	10.2	—	64,800	57,300	6.9	—†				
		5⅝x6⅝	69,100	59,900	9.0	15	61,100	54,700	3.0	3	61,400	54,200	3.0	3
24S–T4	Rod	¾ dia	70,500	42,100	21.3	35								
		¾ dia	71,300	45,300	20.0	30								
		¾ dia	71,700	44,500	20.0	21								
		1 dia	68,600	41,800	22.0	33								
	Plate	¾	69,300	49,800	21.0	—	68,500	45,200	18.0	—				
	Extrusion	1¼x3⅞	74,400	51,900	15.0	22								
		1⅞x6¼	80,600	62,200	14.0	19								
		2¼x3½	75,000	51,600	13.3	—	60,800	46,200	6.9	—				
		2⅜x2½	81,500	62,000	12.3	15	61,300	46,700	9.3	5†				
		2½x3¼	82,200	57,600	13.3	—	66,800	45,300	11.2	—				
		3⅝x6	80,200	59,600	13.1	—	62,800	46,900	7.5	—†				
75S–T6	Rod	¾ dia	84,400	73,000	17.4	29								
	Plate	1	87,400	76,400	9.3	12	85,300	74,200	10.0	15				
		4½	78,300	65,400	10.5	13	67,000	59,300	2.0	3	69,600	57,200	1.7	0
	Forging	⅝x3½	83,200	72,600	9.5	—	82,000	71,200	10.0	—				
		10x15	78,500	69,300	8.0	12					72,000	68,600	1.0	1
	Extrusion	¾x2	89,400	81,100	7.2	16								
		⅞x2¼	86,800	78,500	10.0	—	80,800	72,000	8.0	—†				
		1¼x4½	82,400	70,800	9.8	13	68,800	60,600	3.0	3	70,600	61,800	3.3	2
		2⅝x3	84,200	75,500	10.0	16	75,000	65,500	5.6	—				
		2¾x3¾	91,100	82,600	8.5	—	75,500	67,000	4.7	—				
		4¼x4¼	86,600	77,300	10.3	16	78,800	68,900	8.0	11				
		5⅝x6⅝	80,200	69,300	9.5	13	67,300	58,900	3.0	4	64,800	57,800	2.0	4

* Offset equals 0.2 percent. † No fatigue tests in this direction.

to the diameter at the root of the notch, using the usual simple flexure formula. Actual test values, obtained with this specific notch-type specimen would not, of course, be expected to check values obtained using a specimen of different dimensions. Tests were run at speeds of either 3,500 rpm or 10,000 rpm and the mean stress throughout was zero.

The fatigue results show the variation in regular and notch fatigue values for specific products made from the three high strength alloys 14S, 24S and 75S. Such results are given for two different tempers or heat treatments of alloy 14S, 14S-T4 and 14S-T6, and for 24S-T4 and 75S-T6. Curves (Fig. 2) were drawn so that two percent or less of the individual tests are outside of the scatter bands.

With the smooth fatigue specimens there is more scatter shown for the 75S-T6 products than for the older alloys. The notch fatigue results, however, appear to be essentially consistent in the amount of scatter shown, regardless of product and alloy. There is a tendency for the naturally aged materials, such as 24S-T4 and 14S-T4, to have slightly higher notch fatigue strengths at large numbers of cycles than the artificially aged materials, such as 14S-T6 and 75S-T6. In general the tests cover the range of cycles from about 10^3 to 5×10^5, but data were not obtained for this complete range in every alloy and temper.

To show the effects of direction of working of the products, these same data have been replotted, in Fig. 3. The same scatter band limits as in Fig. 2 are shown for each alloy and temper.

A study of the data reveals that there are relatively small effects attributable to direction of working, particularly for the notch fatigue data, where no differences are found. Al-

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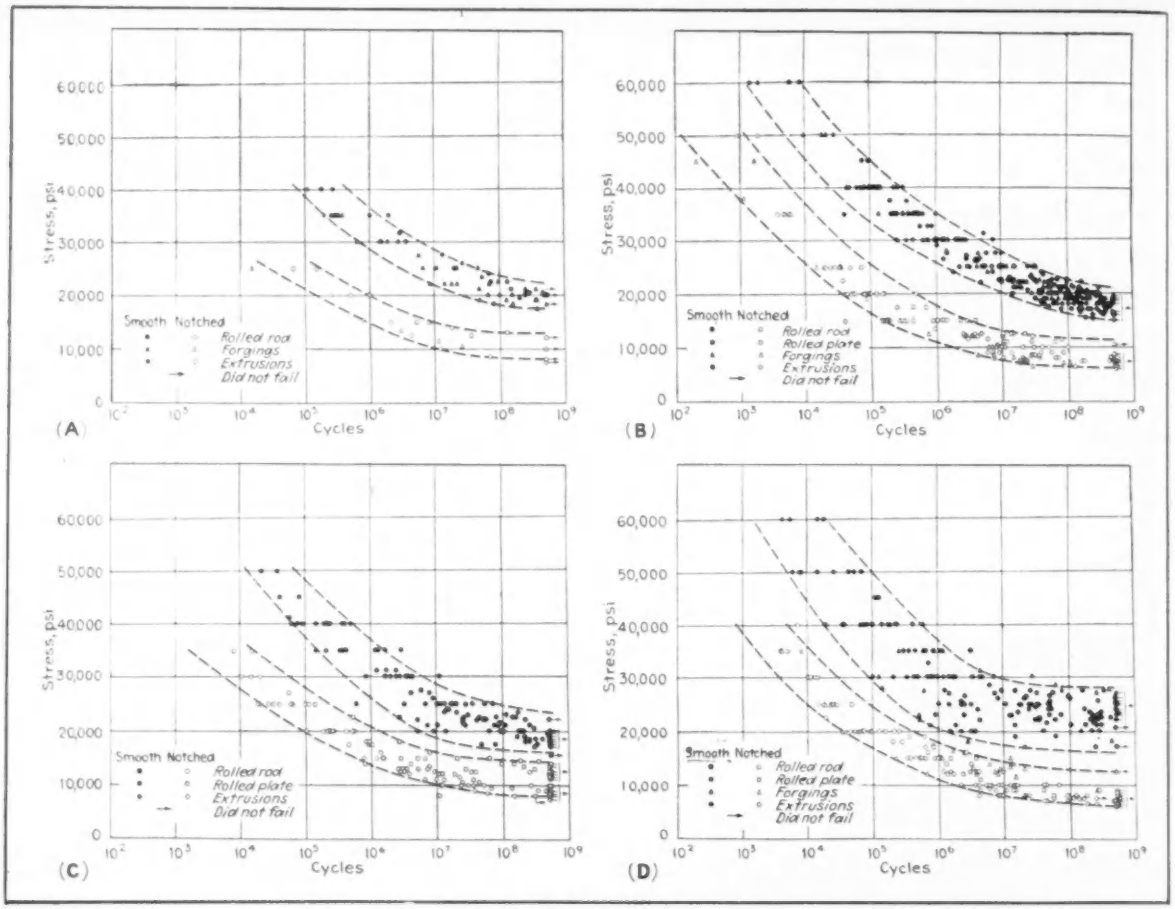

Fig. 2—These curves show the variation in notch fatigue values, based on rotating beam fatigue data for: (A) 14S-T4 products; (B) 14S-T6 products; (C) 24S-T4 products; and (D) 75S-T6 products.

though the smooth specimen fatigue strengths are generally slightly lower in the transverse direction than in the longitudinal direction, the differences are not signficant. Furthermore, there do not appear to be consistent differences for small, intermediate or large numbers of cycles.

An attempt has been made to compare the scatter bands for both the regular and notch fatigue values of all the alloys, products and conditions, by super-imposing the bands, as shown in Fig. 4. The coincidence of the scatter bands for the notch fatigue data is noteworthy. This would appear to be evidence that the presence of a sharp notch in these materials minimizes to a pronounced extent differences in results of fatigue tests on smooth specimens.

Both the width and overlapping of the fatigue test scatter bands suggest that the differences in fatigue strengths, indicated by typical single curve plots of each material, may not be significant in many engineering designs. This point is supported by the fact that similar fatigue data on the same materials from different sources often do not agree within closer limits than the scatter bands shown in Fig. 2.

INTERPRETING DATA

It often is hoped that laboratory tests on small specimens of the type just discussed can be used to indicate the service performance of structures or machines made from the materials tested. In our present state of knowledge such a prognostication probably involves an extrapolation beyond the bounds of good engineering judgment. It is possible, however, to compare results from these simple specimen laboratory tests with fatigue tests of structural components such as riveted, bolted or welded joints, and beams, and attempt a correlation. Although the test conditions for these assembled parts may be known, the actual stresses existing in them generally are not, with the result that the comparisons made may be more impressive qualitatively than quantitatively.

The conclusions drawn from the fatigue results presented in this article are qualitatively consistent with those drawn from fatigue tests of single riveted specimens and box girders made from Alclad 75S-T6, Alclad 24S-T3, Alclad 14S-T6, Alclad 14S-T4, Alclad 24S-T81 and Alclad 24S-T86 sheet, in which zero mean stress was used. When testing both the riveted points and the built-up box girders, the geometry of the specimens was maintained constant for all specimens representing the different materials. The use of Alclad material throughout these two investigations is known to have little or no effect on the small differences between alloys.

A common procedure in the consideration of fatigue data is to attempt to correlate the data with the static mechanical properies of the material being investigated. The results obtained in the investigation have been plotted in Fig. 5, to reveal any such correlations that might exist; only the average endurance limit values (5 x 10^8 cycles) have been plotted against the various tensile properties. The results obtained from different orientations, with respect to working of the

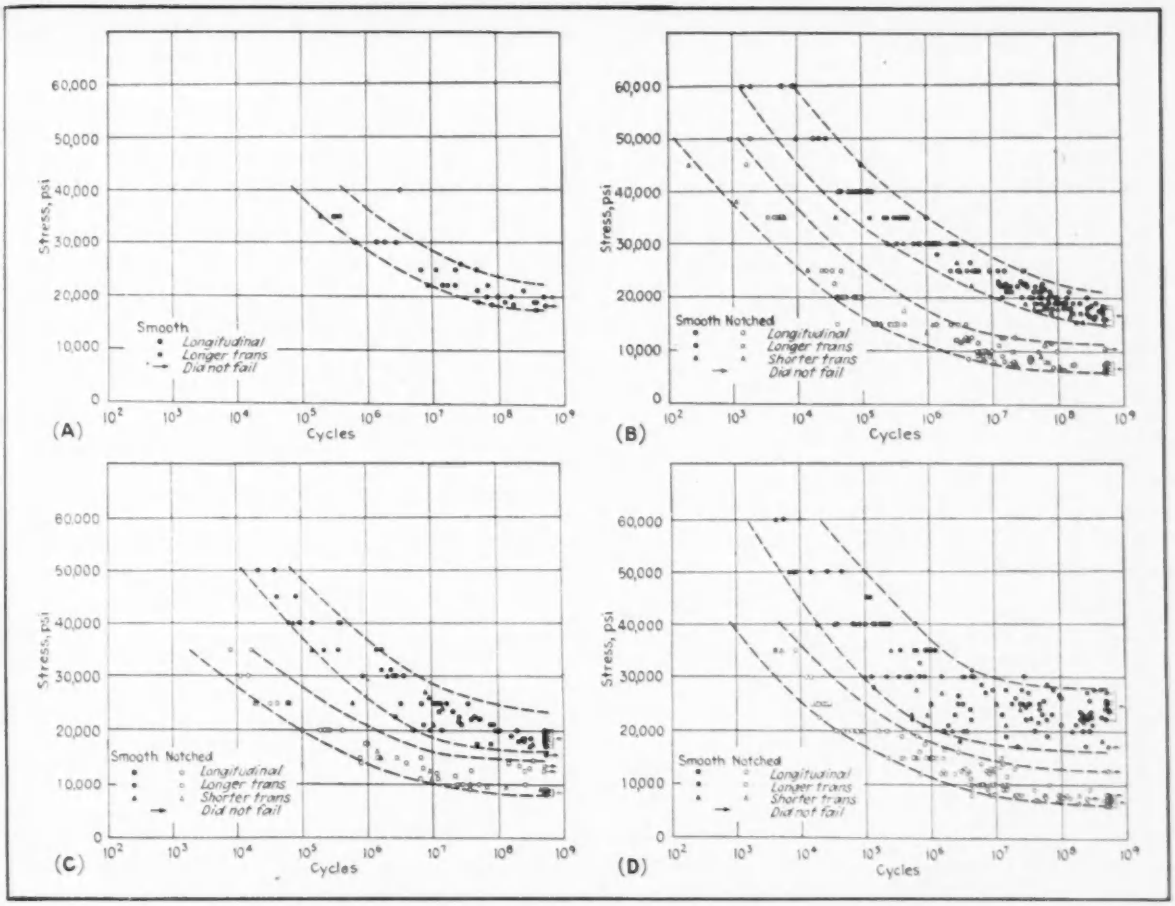

Fig. 3—Replotted to show directional effects, these curves indicate rotating beam fatigue properties of: (A) 14S-T4 products; (B) 14S-T6 products; (C) 24S-T4 products; and (D) 75S-T6 products.

product, have been connected by lines.

The scatter of results evident in Fig. 5 precludes any well-defined quantitative relationship between endurance limits and static properties. There is not even a general qualitative relationship. This is particularly true for notch endurance limits. Similar plots of the fatigue strengths for lower numbers of cycles indicate that the same general conclusion is applicable over the entire range considered.

Mention has previously been made of the severity of the notch used in making these notch fatigue tests. The notched specimen used are believed to give fatigue strengths, at least for the aluminum alloys, about as low numerically as would be expected from any laboratory notch fatigue specimens. Thus, data from other notch specimens should fall within the area defined by the smooth and notched specimen scatter bands shown.

Because of the difficulties in making fatigue tests, as described in the A.S.T.M. Manual on Fatigue Testing, the widths of the scatter bends shown cannot be attributed solely to variations

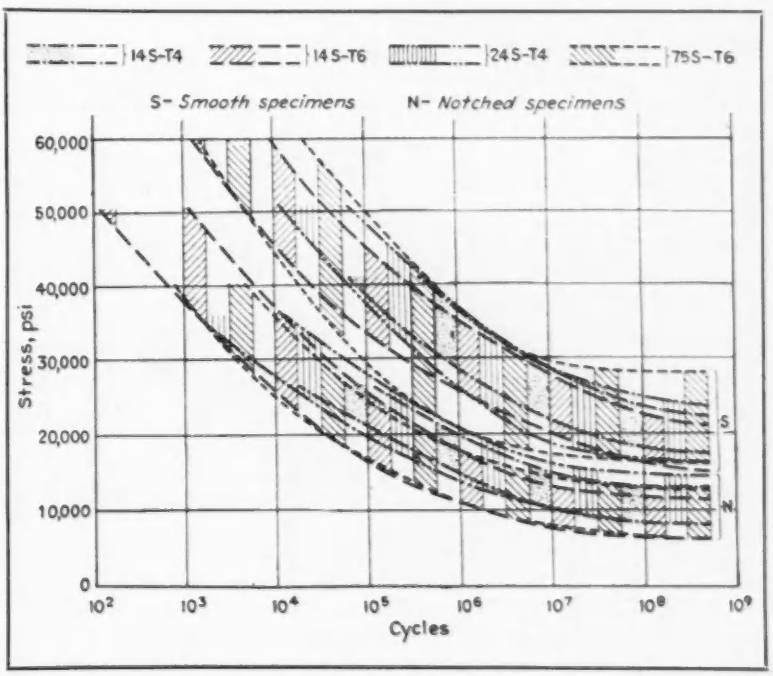

Fig. 4—Comparison of fatigue strength bands of 14S, 24S and 75S aluminum alloys.

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in the fatigue properties of the materials. Testing technique can be responsible for some of the scatter.

CONCLUSIONS

The foregoing discussion of rotating-beam data on various high strength aluminum alloy products can be summarized as follows:

1. The fatigue strengths determined in the transverse directions are not significantly different from those for the longitudinal direction.

2. There is no well-defined quantitative relationship between fatigue strength and the various tensile properties. In general there is not even a qualitative relationship. This is particularly true for the notch fatigue strengths.

3. There seems to be a greater spread in fatigue strengths determined on the smooth specimens than in those determined on the notched specimens.

4. For smooth-specimen data the amount of scatter is greater for 75S-T6 than for any of the other materials. For notch-specimen data the amount of scatter is about the same.

5. When comparisons of notch-fatigue properties are made on the basis of scatter bands rather than on the basis of the data on individual lots of material, there seems to be no clear-cut, consistent advantage for any one of three alloys.

6. Important improvements in resistance to fatigue of actual engineering assemblies can be obtained more effectively and consistently by improvements in design and fabrication than by mere substitution of one high strength aluminum alloy for another. This conclusion is confirmed by fatigue tests of actual structural assemblies.

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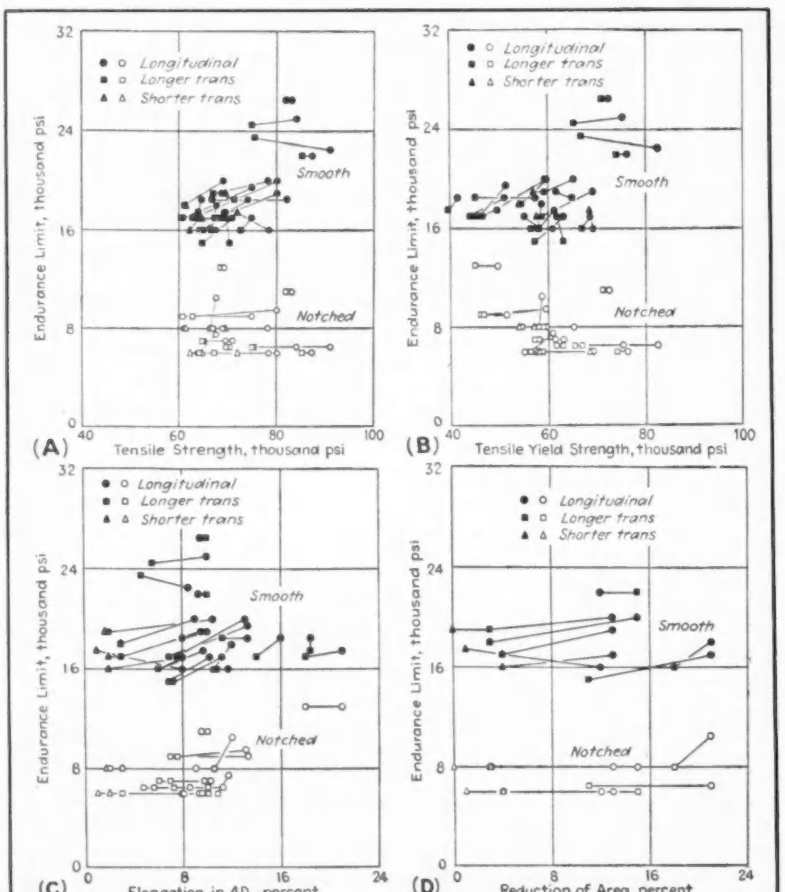

Fig. 5—An attempt to correlate fatigue with static mechanical properties for 14S, 24S and 75S products: (A) endurance limit vs tensile strength; (B) endurance limit vs yield strength; (C) endurance limit vs elongation; and (D) endurance limit vs reduction of area. Both the usual fatigue and the notch fatigue data are given.

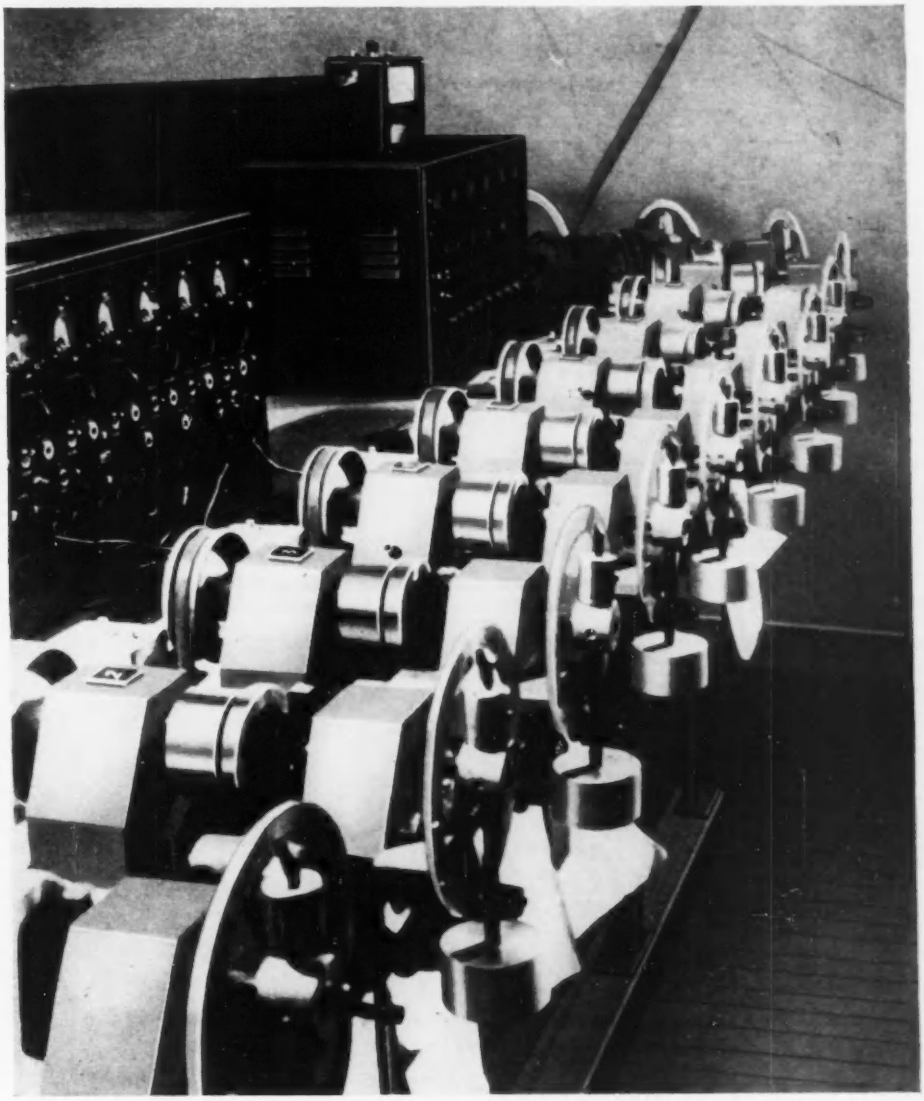

Fig. 1—Magnetic powder clutches on life cycle tests. It is claimed that after one million operations, clutch faces show no appreciable indication of wear.

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Magnetic Powder Clutches Speed Servo Response

THE BULK OF SERVOMECHANISM APPLICATIONS is in fields where precise control, indication or actuation is required. In almost all cases, it is desirable to have the positioner or error corrector respond to the sensing device with a minimum time lag. Such performance is difficult to obtain when conventional electric motor positioners are used. There is an appreciable interval between error sensing and error correction.

It is possible to improve servo motor response by increasing the magnitude of the actuating current. Since the signals from sensing devices are ordinarily small, considerable electronic apparatus is required to get the necessary power amplification.

However, if fluid magnetic clutches are incorporated in the actuator or error corrector, they not only improve response, but function as power amplifiers as well. Their basic advantage is their fast response to extremely small control currents. For this reason, such clutches are of particular value to designers of servomechanisms.

A typical actuator, sketched schematically in Fig. 2, incorporates two mag-

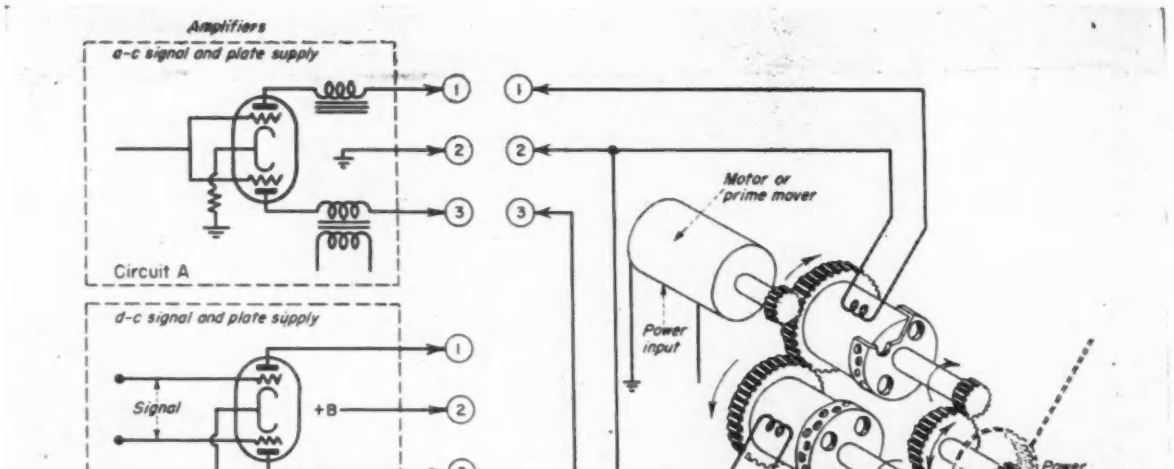

Fig. 2—Schematic of servo actuator and simple electronic clutch control circuit. Sensitive error detectors are used to activate the basic clutch circuits A and B. Output shaft torque as well as its direction of rotation is controlled by the signal.

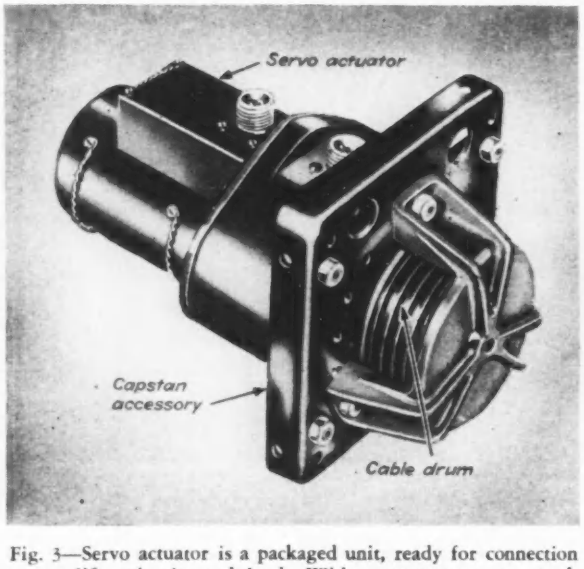

Fig. 3—Servo actuator is a packaged unit, ready for connection to amplifier circuits and load. With capstan accessory, peak torque of 200 lb-in. is available from the actuator.

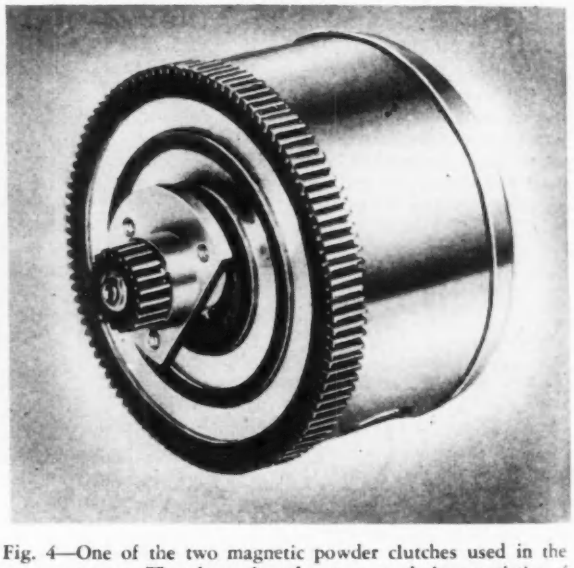

Fig. 4—One of the two magnetic powder clutches used in the servo actuator. They have the advantages and characteristics of the fluid magnetic type but are easier to seal.

netic powder clutches. Made by Lear, Incorporated, this servo actuator consists of a cumulative compound wound d-c motor, reduction gearing and two counter rotating magnetic powder clutches. The clutches are geared to a common output shaft.

In operation, the motor, part of the gear reduction, and the two clutch assembly masses run continuously, thereby providing a source of kinetic energy instantly available to the unit's output shaft by excitation of either clutch coil. The direction of output shaft rotation depends on which of the coils is energized. Output torque is proportional to the excitation current that is admitted to the winding of the active coil.

With 8 ma (equal to 0.64 watt) of direct current flowing in a clutch coil, a torque of 40 lb-in. at 180 rpm (equal to 84.7 watts) is available at the output pinion. This is equivalent to a power amplification factor of more than 130.

The amplification factor can be increased further by use of additional gearing. The capstan accessory shown in Fig. 3, which is designed for attachment to the servo actuator, provides a five to one gear reduction. The capstan has a grooved drum for cable take-off. With the same 8 ma coil excitation, a maximum torque of 200 lb-in. at 36 rpm is available at the cable drum. Included as an integral member of the drum is a clutch assembly, which can be adjusted to slip at any torque up to 250 pound-inches. The drum has a no-load speed of 48 rpm, giving a cable speed of 6.7 in. per second.

MAGNETIC POWDER CLUTCH

The magnetic powder clutch control medium is an iron powdered mixture contained within the air-gap space between two magnetic surfaces. When the clutch coils are energized, a magnetic field is established through the

air-gap. The finely divided iron particles become magnetized, bind themselves together, and span the air-gap in a solid mass. In this fashion the driving and driven members are locked together. Because the driving clutch assemblies are continuously revolving, the mass of iron powdered mixture is in constant motion and through centrifugal action is symmetrically distributed throughout the air-gap. These features contribute to the smooth operation of the driven member and also eliminate any effects due to changing from static to kinetic friction.

Below the point of saturation of the powdered iron, torque output vs excitation is a linear function except in the vicinity of zero excitation. From Fig. 5, it can be seen that by permitting a very small no-load current to each coil, the torque-excitation relationship may be made linear from zero to maximum operation.

Since the powdered iron is not mixed with liquid, there is no problem of leakage or of poor starting characteristics at extremely low temperatures. Furthermore, it is possible to operate the clutch at temperatures up to 250 F, which is the safe limit for the insulating compound used in the clutch coils.

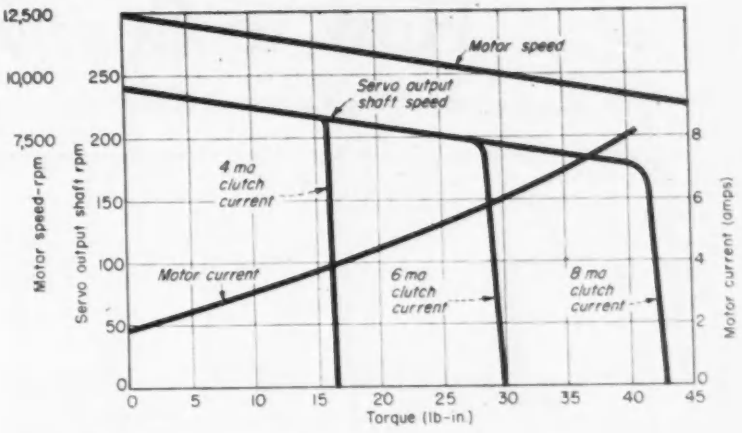

Fig. 5—Curves showing clutch coil current plotted against static output torque. Relationship is linear when one ma no-load current is maintained through clutch coils.

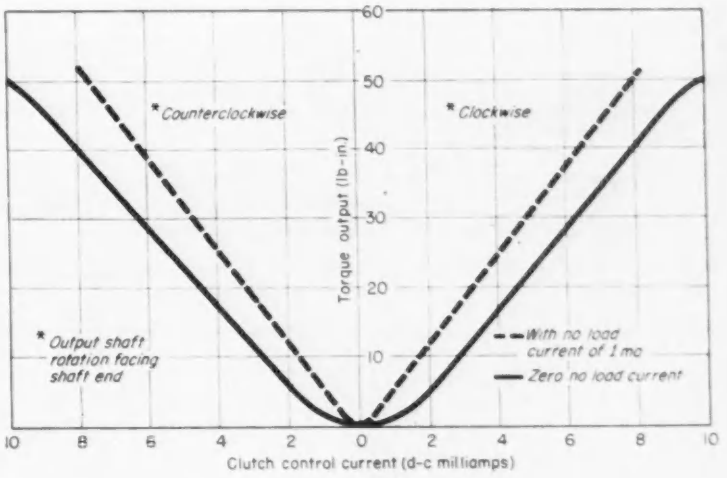

Fig. 6—Load performance curves for the magnetic powder clutch servo actuator. There is no slip between driving and driven clutch members until the torque rating for a given excitation is exceeded. Then, output torque drops to zero.

PERFORMANCE

In Fig. 6 are shown the speed-torque-current curves for the servo actuator without the capstan. The fact that the slopes of motor and servo output shaft speed curves are equal indicates zero slip between driving and driven members of the clutch. Thus, the unit's output shaft speed varies in direct ratio to the motor speed, dropping to zero only when the load exceeds the output torque for any given clutch current input. Essentially this is the characteristic performance of a synchronous motor, i.e., when slippage occurs, the speed of the rotating member drops to zero.

The motor selected to power the actuator is a continuous duty d-c unit, rated at 95 watts. At 10,000 rpm it delivers 0.8 lb-in. of torque. The load requirements determines the safe duty cycle for the actuator. For example, when alternately energizing each clutch to produce a static torque of 40 lb-in. using a duty cycle of $\frac{1}{2}$ sec on, two sec off, the temperature rise of the unit is 140 F maximum. If low output shaft speeds are satisfactory to the application, this type of servo actuator can be used in a continuous duty cycle. The lower speeds are obtainable by changing gear reduction ratio and/or using a slower speed motor. However, many applications require high speeds.

ACTUATOR APPLICATION

The time required for torque build up in this type actuator is about 140 milliseconds when a step function voltage is impressed directly on the coil. When excitation is applied directly via a vacuum tube the time constantly is shortened—about 50 to 80 milliseconds for triodes and 20 to 30 milliseconds for pentodes. By using a lower number of turns in the clutch coils and pentodes of high current capacity, the time constant can be lowered to between 5 and 10 milliseconds.

The control of the clutch magnetic forces over the full power range is simple to accomplish. Generally, the few milliamperes required for the clutch coil (average d-c resistance is 10,000 ohms at 77 F) can be supplied by miniature electron tubes. The schematic in Fig. 2 shows the single-tube clutch circuits often used with the actuator. Any of the standard sensing circuits can be adapted to feed these single-tube circuits.

The elimination of complicated electronic circuits is expected to widen the potential fields of application for servomechanisms. Minute currents from sensitive detecting devices may be utilized to initiate a remote action requiring a high torque.

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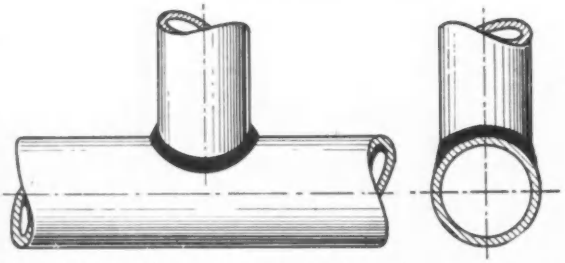
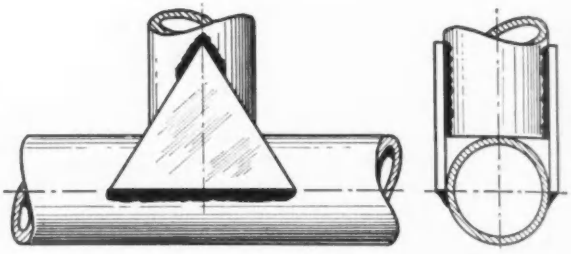
How to Connect Tubing—

Concluding installment of a series of three articles on types of connections used for tubing.

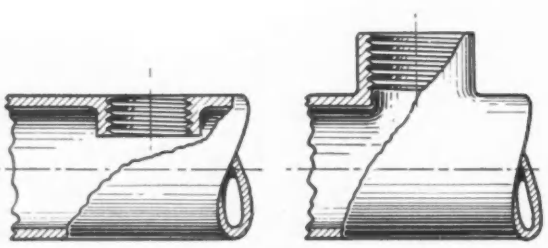
TEE JOINTS



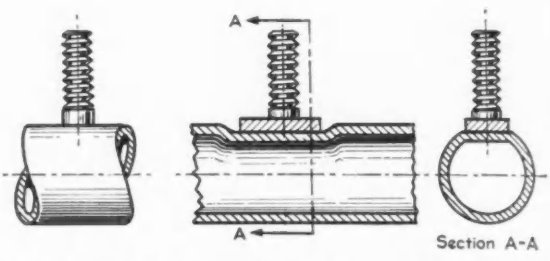
1. Welded joint used for connecting tubes at any angle. Perpendicular member is shaped to fit mating tube.



2. Gusset plate makes a reinforced tubing connection. Attachment can be made by means of a weld, rivets or bolts.

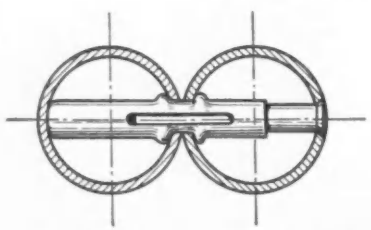


5. Formed flanges simplifies tubing connection. Attachment can be made by using threads or welding operation.

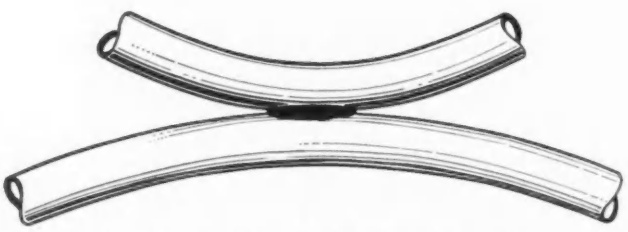


6. Threaded welding studs make a convenient connection. Welding stud to a pad on tubing reinforces joint.

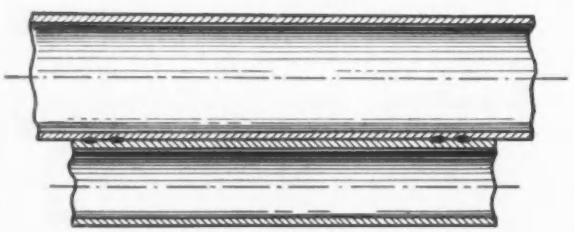
CROSS JOINTS



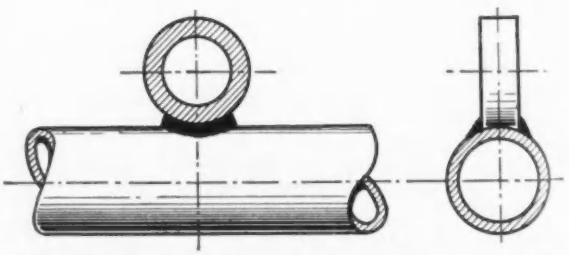
1. Expansion sleeve can be used to join tubes. Split-sleeve is expanded in tubing holes by means of steel drive plug.



2. Curved tubing used as a cross joint; this can easily be connected by projection welding.



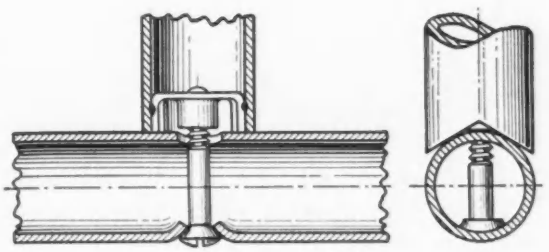
3. Projection welding parallel tubes makes more rigid construction. Air vent tubes can be attached in this way.



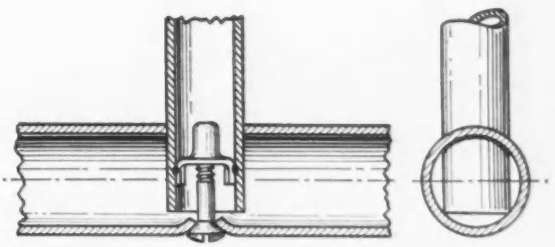
4. Simple guide for other tubing or shafts can be made by projection welding ring to tubing.

Cross and Tee Joints

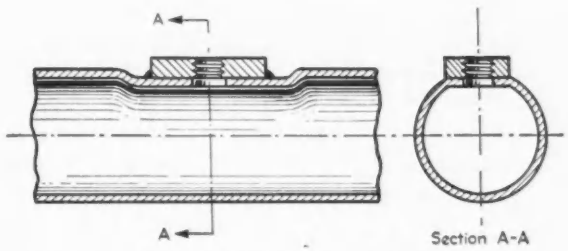
Prepared by the Product Development Committee, Formed Steel Tube Institute, Cleveland, Ohio.

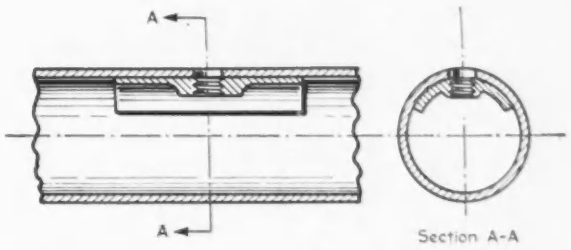


3. Bolted connection is used for racks and frames. Requires a threaded insert and notching the end of joining tube.

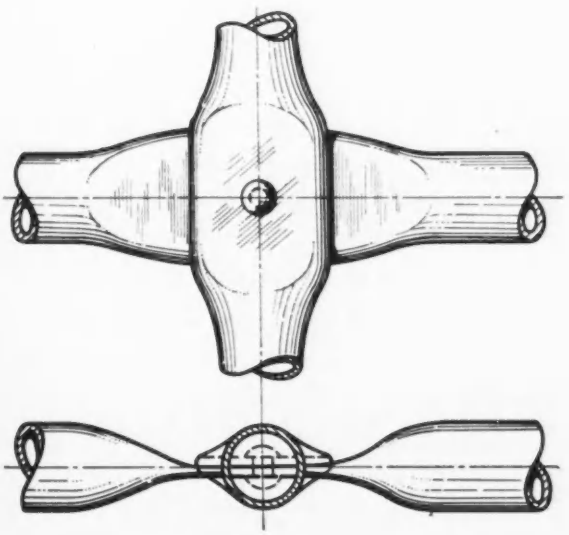


4. Tubes of different sizes can be more rigidly connected by inserting the smaller tube inside the larger one.

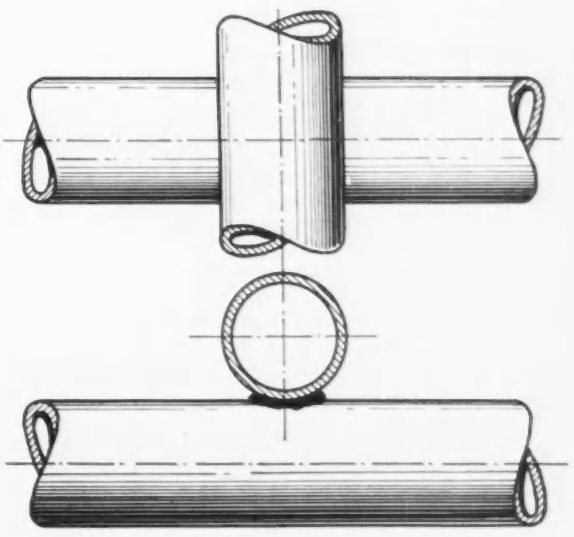




7. Reinforced connection can be made by attaching pads to outside or inside surface. Flattened tubing simplifies the connection for brazing or projection welding. Pads may be threaded either for pipe or screw fitting.



5. Flattened tubing makes joint when tubes intersect in same plane. Connection is welded, riveted or bolted together.



6. Welded connection can be made between tubes in contact. Tubes may cross at any angle.

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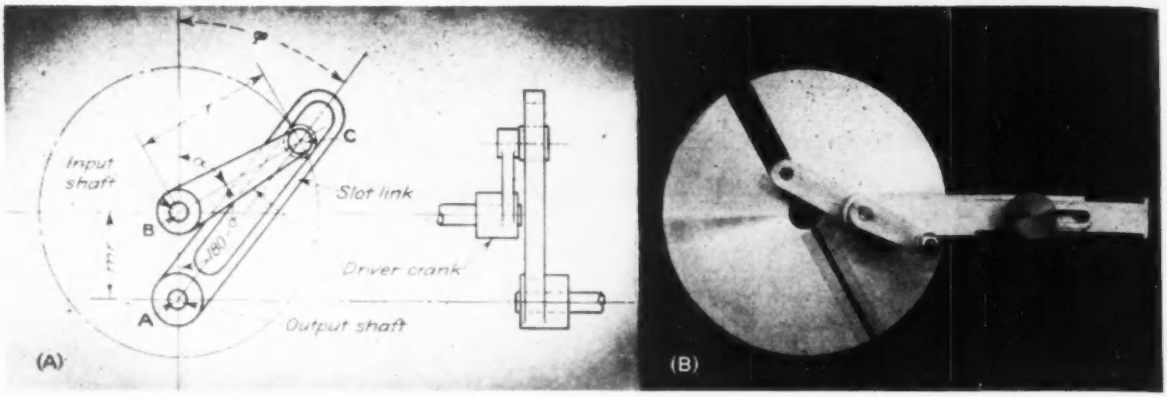


Fig. 1—(A) Schematic sketch of the crank and slot drive. By changing distance *mr*, the non-uniform rotary motion can be varied. The driven member will perform a complete revolution as long as *mr* is kept smaller than *r*. (B) Model of the crank and slot drive having an adjustable center distance. Slot link is replaced by a slot carrying disk for balancing purposes.

Kinematics of the Crank And Slot Drive

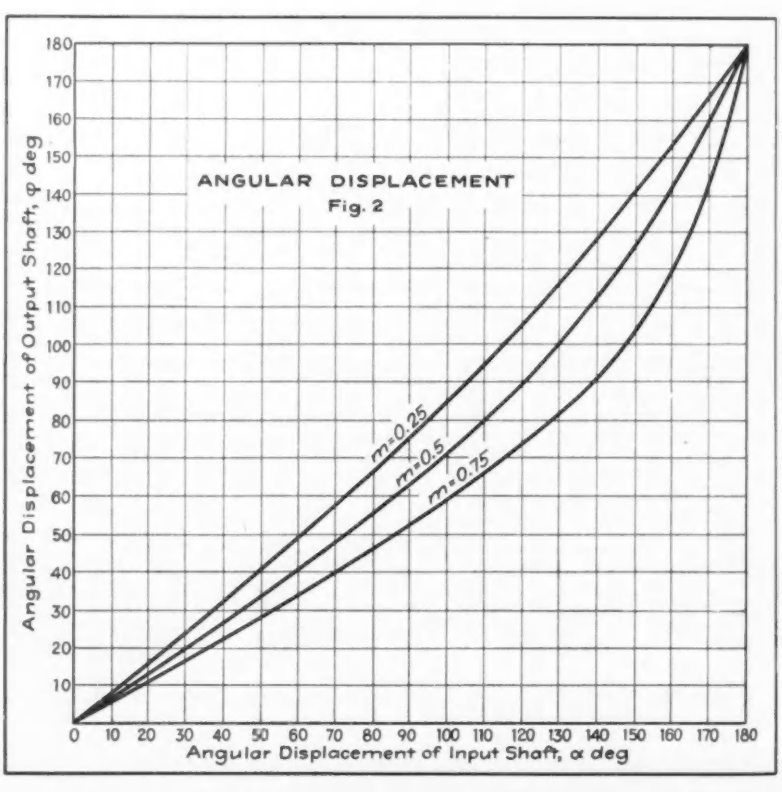
A low-cost substitute for elliptical gearing

S. RAPPAPORT
Consulting Engineer,
Wright Machinery Company

APPLICATION OF NON-UNIFORM ROTATION is sometimes unavoidable — and even to be desired. One frequent application is on rotary cross-cutting knives for continuously moving paper or foil webs.

Here, a fixed length of the web passes beneath the knife during one cycle of the machine, while the knife performs one rotation per cycle. The knife's peripheral speed, while cutting, should approximately equal the web speed, which in turn determines the cut length. Obviously, these conditions can be fulfilled for one particular cut length only if the knife diameter is kept constant. If the paper feed is set for a larger cut length, the web speed increases and the peripheral speed of the knife is relatively too slow.

To overcome this difficulty, elliptic gears are sometimes employed to drive the knife shaft. They cause the knife to accelerate in its cutting position to the approximate web speed and slow


ANGULAR DISPLACEMENT
Fig. 2
Angular Displacement of Output Shaft, φ deg
Angular Displacement of Input Shaft, α deg
m=0.25
m=0.5
m=0.75
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180

down in the remainder of its cycle.

There are other machines for which non-uniform output speed is desired, but elliptic gears are difficult to make and accordingly are expensive. There is, however, another solution for this kind of drive—the crank and slot drive.

It is a comparatively simple mechanism giving similar results. Fig 1(A) shows a schematic sketch.

It is obvious that the driven member, the slot link, will perform a complete revolution for each turn of the driving crank as long as their center distance is smaller than r, the crank length, or $m < 1$; (where m equals a constant by which r is multiplied to equal the distance between input and output shaft centers). For $m > 1$, the slot link will perform oscillations.

The equations of motion then will equal those of the Internal Geneva, PRODUCT ENGINEERING, Aug 1949, p 109, in that part of the oscillation where the direction of rotation is that of the driving crank. The equations will be those of the External Geneva, PRODUCT ENGINEERING, July 1949, p 110, when the slot link is on its backstroke, rotating in an opposite direction to the driving crank.

An advantage of this drive over the elliptic gear drive is the possibility of making the center distance adjustable. Thus it is possible to change the degree of circular irregularity to meet the particular requirement. Fig. 1(B) shows a photograph of a model with adjustable center distance.

For the development of the equations of motion refer to Fig. 1(A). The displacement of the output shaft, ϕ, is found from triangle ABC, where α is the driving crank displacement:

$$\tan \phi = \frac{r \sin (180 - \alpha)}{mr - r \cos (180 - \alpha)} = \frac{\sin \alpha}{m + \cos \alpha} \qquad (1)$$

Curves, Fig. 2, represent this equation for different values of m.

By differentiating Eq (1) the angular velocity of the driven shaft is found:

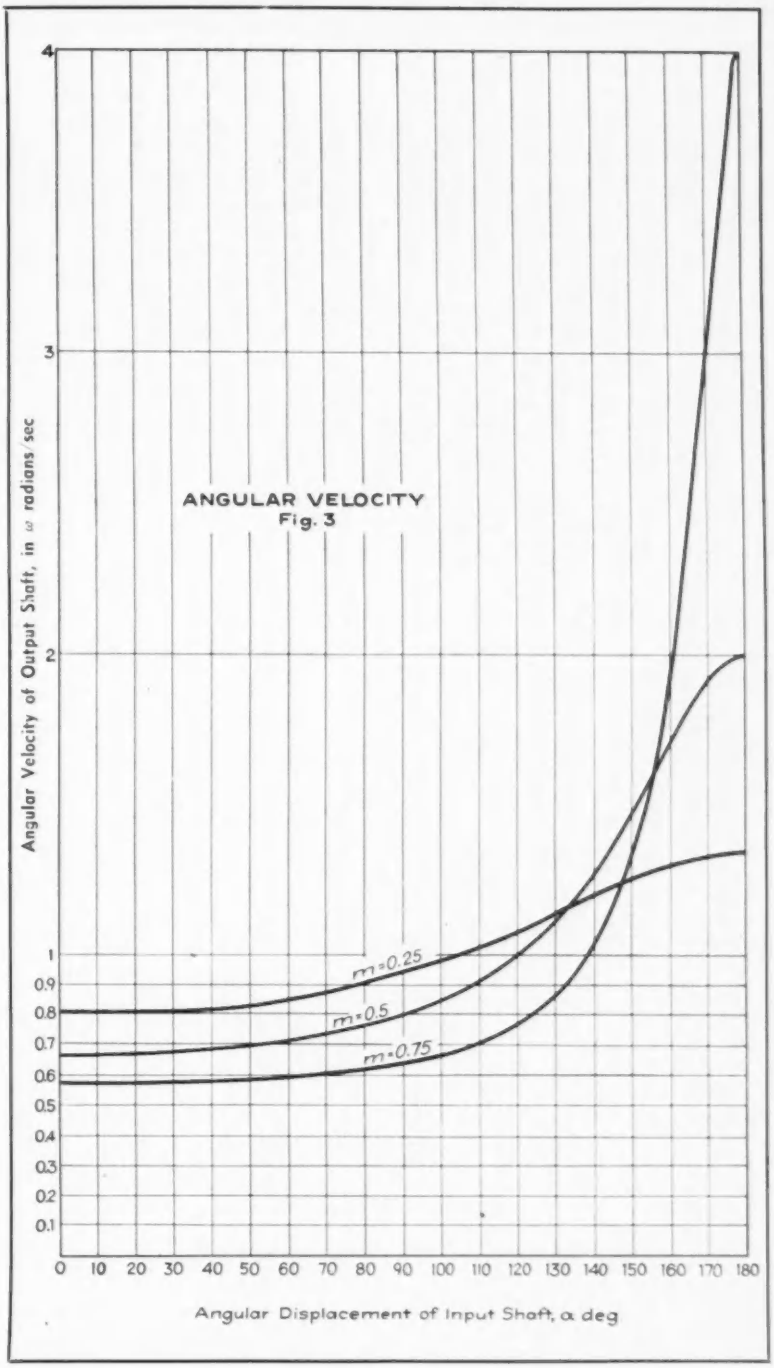
$$\frac{d\phi}{dt} = \omega \left(\frac{1 + m \cos \alpha}{1 + m^2 + 2m \cos \alpha} \right) \qquad (2)$$

where ω is the uniform angular velocity of the driving crank in radians per second. This is plotted in Fig. 3. The minimum velocity occurs at $\alpha = 0$ deg and equals

$$\omega \left(\frac{1}{1 + m} \right)$$

The maximum velocity occurs at $\alpha =$ 180 deg and equals

$$\omega \left(\frac{1}{1 - m} \right).$$


ANGULAR VELOCITY
Fig. 3
Angular Velocity of Output Shaft, in ω radians/sec
Angular Displacement of Input Shaft, α deg
m=0.25
m=0.5
m=0.75
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 2 3 4

These relations can also be clearly seen from Fig. 1(A) taking the ratios between driving crank radius and the limits of the driven slot radius.

The degree of circular irregularity follows as

$$\frac{1 + m}{1 - m} \qquad (3)$$

It is significant that Eq (2) closely resembles the velocity equation of elliptic gears which is

$$\frac{d\phi}{dt} = \omega \left(\frac{1 - e^2}{1 + e^2 + 2e \cos \alpha} \right) \qquad (4)$$

Where $e = \frac{1}{a} \sqrt{a^2 - b^2}$

Here $2a$ is the large axis, and $2b$ the small axis of the pitch ellipse.

The difference between the velocity outputs of elliptic gears and the crank and slot drive lies in the fact that the elliptic gear drive produces a lower velocity minimum than the crank and

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slot drive if the velocity maximum is kept alike in both drives. Accordingly, the degree of circular irregularity is larger for elliptic gears; namely:

$$\left(\frac{1+e}{1-e}\right)^2$$

as compared to Eq (3).

The acceleration curves, Fig. 4, are obtained by differentiation of Eq (2):

$$\frac{d^2\phi}{dt^2} = \omega^2\left[\frac{m(1-m^2)\sin\alpha}{(1+m^2+2m\cos\alpha)^2}\right] \quad (5)$$

The designer is interested mainly in the maximum acceleration, chiefly to calculate the highest force encountered.

To find at what position, α, of the driver the maximum acceleration of the slot link occurs, let

$$\frac{d^3\phi}{dt^3} = 0$$

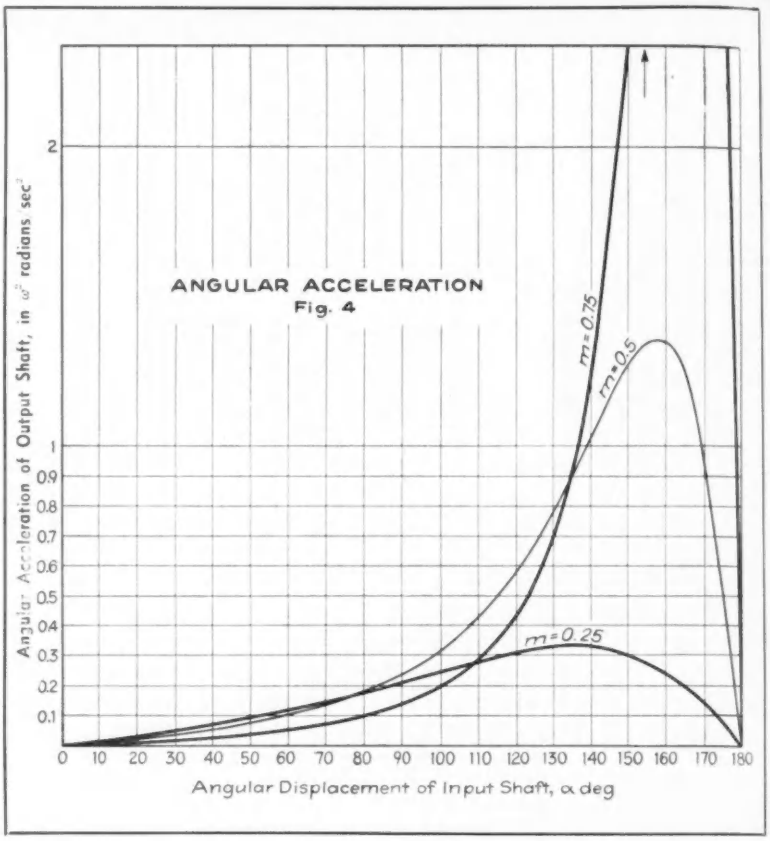
or:

$$(1+m^2+2m\cos\alpha)^2\, m(1-m^2)\cos\alpha + 4m^2(1-m^2)\sin^2\alpha\,(1+m^2+2m\cos\alpha) = 0 \quad (6)$$

from which follows:

$$\cos\alpha = \frac{1+m^2-\sqrt{(1+m^2)^2+32m^2}}{4m} \quad (7)$$

Substituting the value of α thus found into Eq (5) gives the maximum acceleration for the specified dimensions and input speed.



Warborn Leaded Lubricants Finding Many Applications

DURING THE LAST WAR the British and U. S. Navy Submarine Service had to cope with a serious problem: An oil slick floating on the surface of the sea could be a fatal giveaway to a submarine hiding beneath the surface. Propeller shafts, periscopes, disappearing gun mounts, all had to be lubricated to assure proper functioning. The problem was to find a lubricant that would sink to the bottom if any became detached instead of floating to the surface, forming an oil slick.

Lubrication experts approached the problem by trying to increase the specific gravity lubricant so that it would still function as a water- and corrosion-resistant lubricant, but would no longer float. After considerable research and experimentation, a formula was developed in which a calcium-base grease was loaded with finely dispersed powdered metallic lead. Specific gravity of the lubricant was greater than sea water and could no longer form a tell tale oil slick on the surface. Furthermore, lubricating characteristics and water- and corrosion-resistance were enhanced by the presence of lead.

While the development of a non-slick, top-side lubricant served a unique function in submarine warfare, powdered lead as an additive in lubricants has served in many peacetime applications. Lead in the form of fine powder intimately mixed with grease markedly improves its lubricating properties. High quality leaded lubricants contain an average of 20 percent by weight of metallic lead.

In use, the grease acts as a vehicle to carry particles of lead powder to the gear or wearing surfaces where, under pressure, the lead powder coalesces and forms a uniform layer or film of lead. The extremely tenacious lead lining or covering fills score marks, pitted or worn surfaces and thus, in effect, renews them. Once this has taken place, the lead coating itself becomes the bearing surface and, since lead has excellent anti-friction properties, the result is smooth, friction-free, quiet operation.

Lubricants containing metallic lead are exceptionally valuable in applications where gears and bearings are open or exposed to dirt, grit and abrasive materials. The comparatively soft film of lead is capable of absorbing such materials without injuring the bearing surface. By guarding against the combined action of corrosive mine waters and abrasion from slimes and grit, leaded greases have found wide application in the mining industry, in mill table gears and bearings, wire rope and cable, ball mills, hoists and pumps.

The use of powdered lead greases on wire rope, which consists of strands of wire surrounding a central core of hemp rope, is noteworthy. This special grease is applied to the hemp to prevent excessive squeezing of the individual fibers, as well as to provide continuous lubrication for the internal wire strands.

There are several lead greases on the market which contain the triple combination of metallic lead powder, litharge and lead soaps. Such combinations result in lubricants that reduce friction and consequently lower the operating temperature. They have an increased load carrying capacity besides preventing wear and corrosion.

ENGINEERING ABSTRACTS

FOREIGN AND DOMESTIC ARTICLES

Use of Special-Purpose Bearing Assemblies

Foreign abstract from the "The Effect of Design Limitations on the Use of Ball and Roller Bearings" by H. D. Birdsey, Mechanical World, November 25, 1949, page 609.

THE AUTHOR USES AIRCRAFT ENGINE DESIGNS to illustrate his points because space is so often a factor in aircraft construction. The principles he develops can, however, be applied to any construction in an instance where redesign requires a group of bearings to carry a higher load, and existing space will not allow the use of larger standard bearings.

When it is impossible to fit a standard bearing of larger size and capacity into the existing space, the author gives these alternative solutions to the problem: (1) the use of either the inner or outer members of an orthodox roller bearing with the addition of its cage and rollers, the other tracking surface being provided by the shaft or housing suitably prepared for this duty. (2) The use of the cage and rollers alone, without either the inner or outer rings, the tracking surfaces being provided by the shaft and housing respectively—after they have been suitably processed to enable them to function as such.

In the last case, the shaft and housing should be made of a material that can be either direct or case-hardened to give approximately Rockwell 60-64 C scale hardness, (nickel steels are often used), and they must be ground to a high degree of accuracy. The surface finish must be first class, with provision made for the diametrical clearance specified by the bearing manufacturers.

The standard type of roller cage locates on the shoulders (or outside diameter) of the inner ring and these must be re-produced on any component designed to use the cage as a single unit. These shoulders may be made integral with the inner track, or they may be separate components. In the second case, the plates acting as the shoulders are made an interference fit on the shaft proper, assembly being facilitated by immersion in hot oil.

In many applications it is inconvenient to have shoulders and in such a case roller cage assembly may well prove a reasonable solution. Here the cage bore is reduced sufficiently to allow it to locate on the shaft proper, clearances being the same as those adopted for a normal assembly. Many types and sizes of these bushes have been designed and produced, ranging from the simple single row to the multiple row staggered roller type.

Epicyclic planet gears are usually rather tricky problems that may well be solved by the application of a roller bush. Quite often small pinions are allied with comparatively large shafts thus severely restricting the allowable bearing space. Again, the loadings are sometimes extremely high in relation to the actual bearing size and a multiple-row roller assembly forms a very compact, high load carrying solution to the problem. When dealing with units that have high rotational speeds, lubrication requires very careful consideration because centrifugal force tends to throw the oil away from the bearing and therefore the usual methods are a little chancy. One well-proved system is to employ a force feed, the lubricant being fed through the hollow pin and distributed to the rolling elements by means of oil holes.

The article concludes with a detailed discussion of sliding bearings.

Shock-Resistant Thermosetting Plastic

Foreign Abstract from "A Shock-Resisting Plastic Moulding Material," in The Engineer (British), p 157, August 5, 1949.

THERMOSETTING PLASTICS have been welcomed by designers of electrical apparatus, who find in them materials of construction that fulfill functional requirements of insulating properties, heat resistance and mechanical strength.

The question arises whether plastic molding materials can prove their value on mechanical strength only. The tensile strength of thermosetting moldings is lower than that of the common metals. The comparison has, however, a different aspect when one considers the strength-weight ratio of the materials, and a cellulose-filled phenolic plastic can successfully compete with the usual metals of construction when tensile or flexural stresses are considered.

These molding compounds are also suitable for applications where high resistance to shock is required. The nature of the fibrous filler contained in the compound determines the resistance of the molding to the impact of a relatively large force which may act suddenly on the molded article. When moldings are subjected to mechanical shock, and there is not enough time for the stress to distribute itself evenly, the filler has to absorb the mechanical shock waves and to prevent failure. A new material, "Rockite 3932" contains a filler which possesses high damping capacity and consequently is claimed excellently to fulfill this function.

Fibrous fillers form an important constituent of molding compositions. Apart from reducing the cost and improving the handling properties of the resin during processing, their chief function is the improvement of impact strength. During flow, the fibers do not dissolve in the resin but form with the bonding agent a non-homogeneous mixture. They are capable of absorbing mechanical shock waves and will prevent propagation of microscopic surface blemishes through the molded article.

It had been found essential to the satisfactory absorption of mechanical shock waves that the filler particles should overlap over a considerable portion of their total length. To a certain extent this condition was fulfilled with diced fabric compounds. Because of the stiffness of the individual diced pieces or flakes, laminated structures were often formed which showed weaknesses in certain directions. A twisted yarn or cord proved, it is claimed, to be the filler which had all the desirable properties. Built up from cotton fibres of good absorptive properties, it takes enough resin to render the finished molding sufficiently resistant to moisture. The right amount of "twist" in the cord is important; it gives strength to the individual filler particles and controls the resin absorption. The length of the cord particles can conveniently be

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adjusted to suit the requirements of flow and strength.

The manufacturing process for this new material consists mainly in the treatment of the filler with a liquid phenolic resin of fast cure. The conditions have to be carefully adjusted in order to maintain the valuable "twist" in the cord.

As a thermosetting molding compound, "Rockite 3932" is said to have all the desirable properties of this class of plastics. It is rapid setting, and gives moldings which show good gloss, and do not require any after treatment, such as polishing. The new material complies with the requirements of B.S. 771 (similar to our ASTM standards) in regard to electrical and mechanical properties. The material should be molded at 300 to 330 F under pressure of 1 ton per sq in. and higher, taking into account the "draw" of the molded piece.

Improving Cam Mechanisms

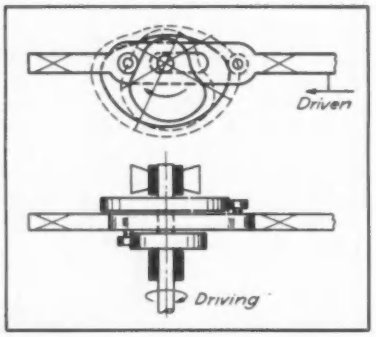
Foreign abstract from "The Improvement of Cam Mechanisms" by P. Grodzinski. Mechanical World (London), p 179, February 17, 1950.

THE PERFORMANCE OF CAMS can be improved in various ways. Among these are correction of the cam shape to maintain the proper pressure angle —basic diameter ratio, use of attachments for the generation of cam profiles from templates and the combination of crank and gear mechanisms.

Of the commonly used cams, the groove type has the characteristic wherein the roller rides on one or the other of the groove faces. Real form constraint is therefore nonexistent and the clearance between roller and groove sometimes permits flutter, resulting in vibration and noise. There are two possible solutions: (1) Use two rollers in the groove, one for each face or (2) utilize a cog-shaped cam with rollers operating from opposite sides.

The double-roller type can be arranged in three different ways: A conventional groove with the rollers fixed on an eccentric pin; and double grooves, one having an undercut, with identical concentric rollers, or a stepped groove with concentric rollers of different diameters. For these cams, correct pitch line must be noted.

In the cog-type mechanism no special form of the cam profile is required, as it consists of a cylinder rim. But in the case of more irregular forms, the two curves are no longer concentric. For such non-concentric curves the follower device can be suspended on a balance lever, turning on a central pivot. This ensures that the two rollers remain in contact with the two cam profiles, as they adjust themselves in a direction giving the required distance. Also, in this instance, it is usually more expensive to produce the double cam profile.



The best solution, according to the author, is the so-called complementary cam which is composed of two open cams as shown. Open cams contain a minimum of mass, can be designed for minimum acceleration, have perfect form constraint, are relatively cheap to produce and change.

The principle is that the main cam is designed as an open cam. Then the path of an arbitrary point connected with the follower lever is traced and a corresponding cam formed. The second or complementary cam will nearly always be of different shape. Only in the case of a follower on a slide and a symmetrical arrangement of pauses will the two cam profiles become reduced to a single cam profile.

Since cams are intricate parts of mechanisms, difficult to design correctly, difficult in construction and ultimately difficult in operation, investigations should be made to determine how the number of cams can be reduced. In such a case, the cost of a machine can be lowered and, by increased care in the production of the absolutely necessary cams, the performance of the machine improved. It is possible to operate several follower levers with one cam and, in another case, operate a swinging lever from one cam profile and simultaneously a slide, thus changing the start of the movement and the angle of operation. It may also be possible to have a second movement follow a main cam for most of its cycle. In this way, movements, which seem to have nothing in common, can be obtained from a main cam. The actual stroke or lift is not important, as it may be changed by levers arranged between the follower lever and the parts to be moved.

Besides the actual cam, the follower roller is the cause of most troubles, usually because of its restricted size. For open cams, the roller is preferably attached to a yoke which acts as a support for the roller pin. This is, however, not possible in the case of face or grooved cams, for which the stud can only be supported from one side. Usually, hardened rollers rotating on a pin are applied but the intermittent shock loads are difficult to carry on such a simple bearing, which is subjected to rapid frictional wear at high speeds. For this reason, cam followers with needle bearings were introduced.

Review of Non-Destructive Testing Techniques

Foreign abstract from "The Non-Destructive Testing of Steel Castings and Forgings", by J. Rhodes, T. H. Arnold and H. S. Peiser, The Institute of Marine Engineers Transactions (London) 1949, Vol. LXI, No. 2.

MANUFACTURERS AND USERS OF MATERIALS of all kinds have always desired means of testing their products and supply materials without rendering them useless for further service. As a result constant efforts have been made to develop new techniques of non-destructive testing. In this paper, the authors review the progress that has been made.

The methods of non-destructive testing of steel specimens are grouped into six principal sections: proof loading tests, metallographic methods of detecting surface defects, radiography, crack detection, magnetic and electrical tests and X-ray crystallographic methods.

Proof loading tests are described and an example is given of a casting which could only be fully inspected by this method. The methods and use of acid etching and sulphur printing are also described.

In describing the techniques of radiography by X-rays and gamma-rays the factors governing sensitivity are especially considered, leading to an assessment of the uses and limitations of these methods. Some recent

developments of new equipment are described and their possible applications are discussed.

Three methods of crack-detection are described: magnetic, fluorescent and supersonic. A number of alternative techniques are available for magnetic crack-detection and the relative merits of these are discussed. The uses of supersonic flaw-detection are described for transmission and reflection techniques.

The effect of the physical condition and the presence of defects in specimens is considered in relation to their magnetic and electrical properties. The cyclograph and the Salford magnetic sorting bridge are described, in which comparative measurements of these properties are made using a specimen of known quality as a standard.

X-ray crystallography is not primarily a method of non-destructive testing, and in the past has only been used very occasionally for the detection of stressed components.

Rotation of Disks in Liquids

Abstract from "Resistance to Rotation of Disks in Liquid" by Austin A. Church and Stanley A. Gertz, A.S.M.E. Paper No. 49-A103.

TESTS TO DETERMINE the retardation of a disk rotating in oil and in water are described. Their purpose was to investigate the influence of viscosity and specific weight of fluid, and also disk side clearance, on hp absorbed.

The test chamber consisted essentially of a 16 in. disk mounted on a shaft for rotation in a stationary housing. Variations in side clearance were obtained by rotating threaded sideplates in the housing.

The specific weight of water used in the tests ranged from 62.1 to 61.1 lb per cu ft, and the kinematic viscosity varied between 7.5×10^{-6} and 4.8×10^{-6} sq ft per sec, these values correspond to a temperature variation from 96 to 150 F. The specific weight of oil used ranged from 53.5 to 51.0 lb per cu ft, and the kinematic viscosity varied between 3.8×10^{-4} to 7.0×10^{-6} sq ft per sec, these values correspond to a temperature variation from 150 to 262 F for oil.

From the results of experimental data, the authors suggest that the following equation be used to determine disk friction horsepower.

Where

γ = specific weight of liquid, lb per cu ft
η = kinematic viscosity of liquid, sq ft per sec
δ = ratio of side clearance to tip diameter
d = tip diameter of disk, in.
N = speed of disk, rpm
H = disk friction horsepower

$$H = 0.00725\gamma\eta^{0.066}\delta^{0.11}(d/10)^{4.67}\times(N/1{,}000)^{2.935}$$

The chart, Fig. 1, is presented to facilitate the use of this equation for disks rotating in water. The dash lines in the chart indicate its use. Here the disk friction horsepower is determined for an 18 in. dia disk, with a side clearance of 0.18 in., rotating at 1,500 rpm in water at 100 F. With this chart, disk friction for any impeller can be determined quickly.

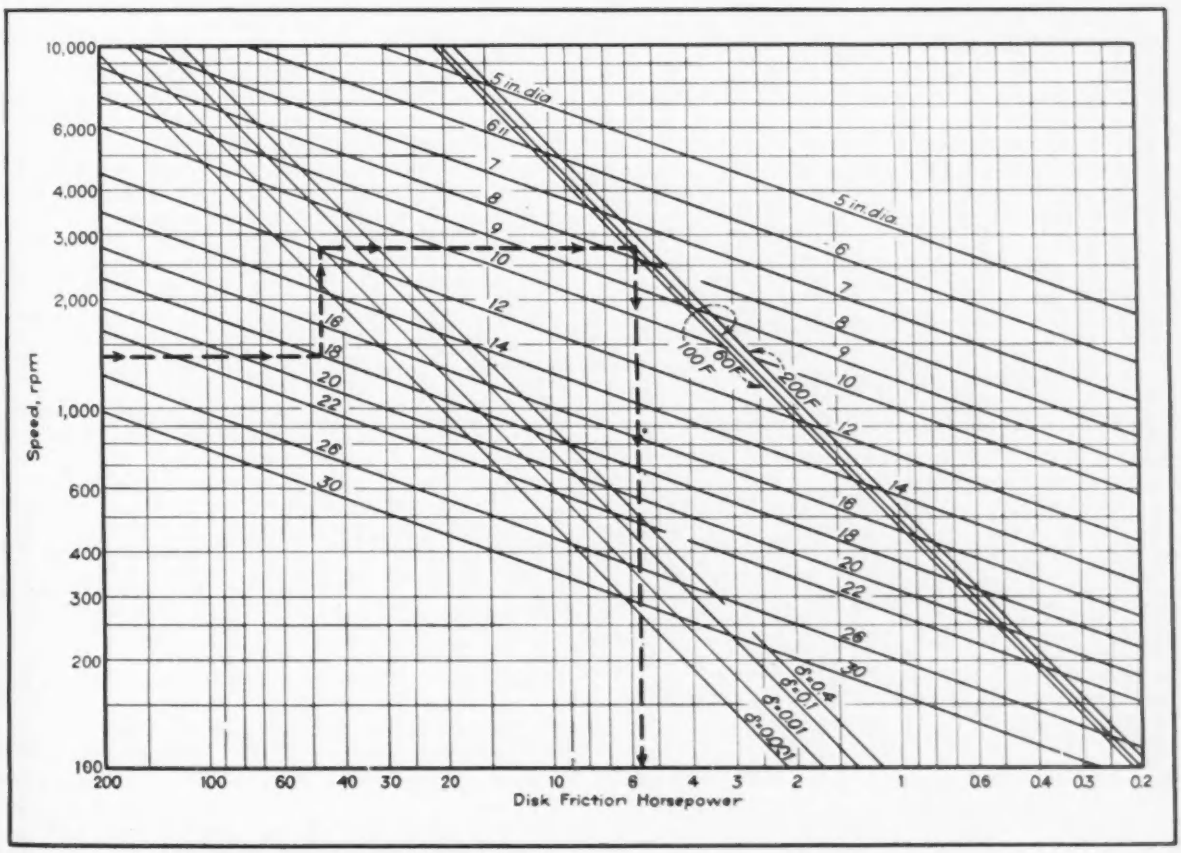


Fig. 1—Horsepower absorbed by a disk rotating in water at different temperatures.

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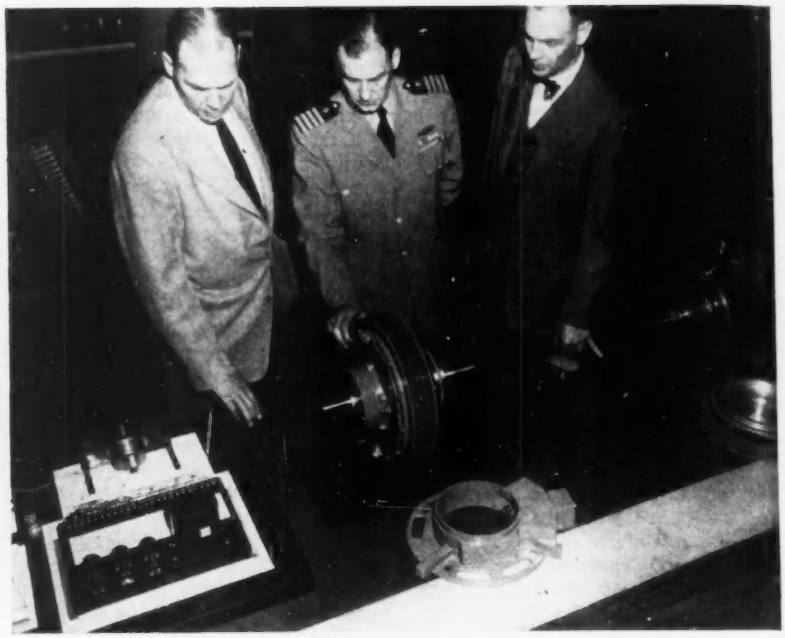
The Magnetic "Fluid" Clutch Comes of Age



WASHINGTON—The magnetic clutch has moved from the laboratory to the field of commercial application. The Navy's Bureau of Ships recently displayed an improved magnetic clutch and associated control equipment built by Vickers Electrical Division, Vickers Corp., St. Louis.

Navy has placed a good-sized order with Vickers for high frequency motor generator sets for shipboard and submarine power use. Research on these sets has led to the development of Vickers "Magneclutches" and "Magnebrakes"—the first magnetic-brake equipment not limited to low power to be produced in quantity and placed in service.

It is not yet possible to buy items off the shelf, but Vickers expects to have a standard line of clutches available within a few months. These clutches will be useful in certain machine tool and servo-applications. The Magnebrake, it is said, can replace friction type brakes in many cases.

The magnetic fluid clutch, from which the Vickers model was developed, was invented by Jacob Rabinow at the National Bureau of Standards and announced by the Bureau in April, 1948. It gave promise of wide industry application for control of power machinery and for use in the automotive fields. To date, the Bureau reports that over 2,000 companies in this country and in Europe have expressed interest in the clutch and the magnetic fluid, and well over 1,000 companies have sent representatives to the Bureau to get more data on the equipment. Two officials from Philips, Holland (largest electronics manufacturers in Europe) were among these inspecting the magnetic clutch.

This device which should more properly be called a magnetic powder clutch, as developed by Vickers, differs from the NBS design in that it makes use of iron powder, lubricated by graphite instead of an oil lubricant. This avoids the problems of evaporation and shaft seals encountered, more particularly, in the early models of the Bureau's clutch.

In equipment shown by Vickers in the Navy demonstration, the magnetic fluid clutch is used as a coupling between an induction motor and a generator for the purpose of automatically maintaining the generator speed or frequency at a constant value. To accomplish this, the clutch excitation is varied, which results in a change in clutch slip as the induction motor speed changes due to its own slip-load characteristics and due to supply line frequency variations. The control current or excitation for the clutch is provided by the frequency output of the generator.

Generator voltage control is achieved by varying d-c excitation for the generator, which is derived from a magnetic amplifier type voltage regulator. The static magnetic amplifier type voltage regulator is essentially a field supply that automatically adjusts the generator field current to the value required to maintain constant line voltage. The voltage regulator as well as the static amplifier components of the frequency regulating system are devoid of any moving mechanical parts and are therefore inherently shock resistant and essentially free of extensive maintenance problems.

Vickers clutches consist of two simple cylinders, one inside the other, with the space between them filled with a mixture of iron powder and powdered graphite. Centrifugal force produced by the rotation of the clutch members keeps the powder in the gap so that only a very small amount of the mix is required. One of its main advantages is that the electrical control is facilitated by the small amount of electrical power required by the clutch.

Advantages of the Vickers clutch are given as:

1. High torque for a relatively small size, for on-off applications.
2. Coil power requirements are low.
3. Can be slipped continuously without wear and yet can be locked in to transmit power at no slip.
4. Its torque is not a function of slip, but is essentially independent of slip. That is, in bringing a high inertia load up to speed, the same torque is available when the load is almost up to speed as when the load is just being started.

NBS, also working under Bureau of Ships contract, is directing its research on problems inherent in its own liquid-type clutch and also those common to all clutches. Sufficient progress has now been made on both counts so that the Bureau believes the main problems have been overcome and future industrial adaptations will depend only on engineering details.

The question of whether one decides on a liquid or dry type magnetic clutch depends in part on the uses to be made of it and in part on the user's own preference. The Bureau is convinced that more smoothness can be obtained with the liquid clutch, having tried both types. However, the Vickers model may be cheaper and have certain other advantages. Most of the

clutches now in process of development by other companies than Vickers are using the liquid method. Other companies manufacturing the clutch are Raymond Engineering Laboratories, Middletown, Conn.; Dynamatic Corp., Kenosha, Wis.; Duncan-Bayley Buffalo, N. Y.; and Lear Inc., Grand Rapids, Mich.

TV Tuner Is Simplified by Printed Circuit Design

A DEPARTURE FROM CONVENTIONAL WOUND-COIL UNITS, RCA's new "printed-circuit" television tuner utilizes a unique photo-etch process to reproduce the critical circuits. The process eliminates the complicated process of mechanically winding separate coils, and at the same time produces precision circuits of superior performance.

With tuner design involving twelve channels, each containing four tuned circuits, the printed circuit technique is especially well adapted to its manufacture. Up to this time, the large number and complexity of circuits, together with the extreme precision of windings required, has presented numerous problems to designers as well as to production enngineers.

In design, the new RCA unit is a cylindrical turret-type tuner. The turret assembly employs individual coil strips or segments, each containing the printed circuit for a separate television channel. The strips are easily removed for service or replacement. All the tuned circuits are printed with the exception of the oscillator coils for channels two to six.

Foundry Show Features "C" Process

SHOWN RECENTLY at the Foundry Show in Cleveland, a new process for producing foundry molds and cores combines the advantages of increased production, reduced cost, and improved quality of the casting.

The new foundry method is known as the Croning Process, for which Crown Casting Associates, 75 Federal Street, Boston, Mass., own and control United States and Canadian patent application. Crown is granting licenses to users for this process which was developed by Johannes Croning of Hamburg, Germany.

Using a phenolic resin-binder, the process was exhibited by Bakelite Division, Union Carbide and Carbon Corp., at the 1950 National Foundry Show in Cleveland. The demonstration included the actual production of molds and the pouring of metal, based on data supplied by Crown Casting Associates.

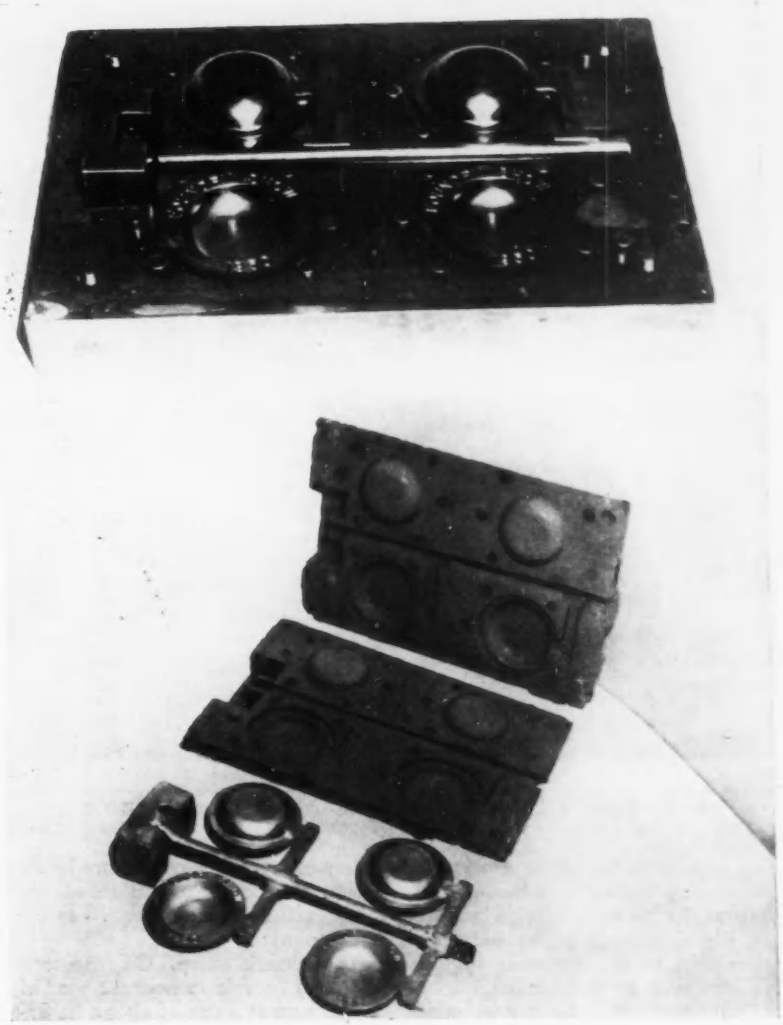
The main advantage of the process is extreme precision. Other advantages of the Croning Process, according to Crown Casting Associates, are: the castings require little or no finishing such as sand blasting or wheel abrating; tolerances of 0.002 to 0.003 of an inch per inch can be common practice; and greatly increased productivity of the floor space.

A saving of up to 90 per cent in the amount of sand required is realized because the new molds are thin shells bonded with phenolic resins as contrasted with the heavy, cumbersome sand mold. Long baking and curing is not required.

In some instances where holes are required in the casting they can be formed in the mold or core, and subsequent drilling is eliminated. The cleanliness of the new process, together with the reduced manual labor involved, can promote easier, cleaner and more healthful conditions for the foundry worker.

Cores are made in the same manner, except that the resin-sand mixture is blown into a hot split metal core box by means of compressed air. The excess material falls out when the flow of air is stopped. The cores are, therefore, hollow and have the same wall thickness as the molds.

Since the cores and molds have no affinity for water and have no volatile



UPPER PHOTO SHOWS the metal pattern used in producing the molds for the Croning Process. A mixture of sand and phenolic resin is applied to the face of the hot pattern until a thin layer is built up, which is baked in an oven until hardened. The lower photo shows two half molds and the casting made from them.

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contents, they can be stored indefinitely until needed.

To prepare the mold for casting, two halves are held in a box with the gate vertical while the surrounding space is filled in with steel shot. The bedding supports the thin mold shell so that it will resist the hydrostatic pressure of the liquid metal and maintain dimensional stability.

Several other companies offer essentially the same process. Durez, Monsanto, and Borden use the term "C" process instead of "Croning".

Electronics Components Studied In Symposium

THE CONFERENCE ON IMPROVED QUALITY ELECTRONICS COMPONENTS held recently in Washington attracted over 800 representatives from industry and government, including approximately 40 engineers and scientists from Canada, England, Australia, Sweden and New Zealand. The Conference was sponsored by the American Institute of Electrical Engineers, the Institute of Radio Engineers, and the Radio Manufacturers Association cooperating with the Department of National Defense and the National Bureau of Standards.

As was expected, emphasis was placed on the problems encountered by the military services in the use of electronics components. Several speakers stressed the difficulty of the services in training a sufficient personnel to maintain electronic equipment. L. V. Bertner of the Carnegie Institution of Washington stated that electronics equipment is imperative for combat effectiveness, yet "it will fail in a large proportion of cases through lack of maintenance personnel in time of war."

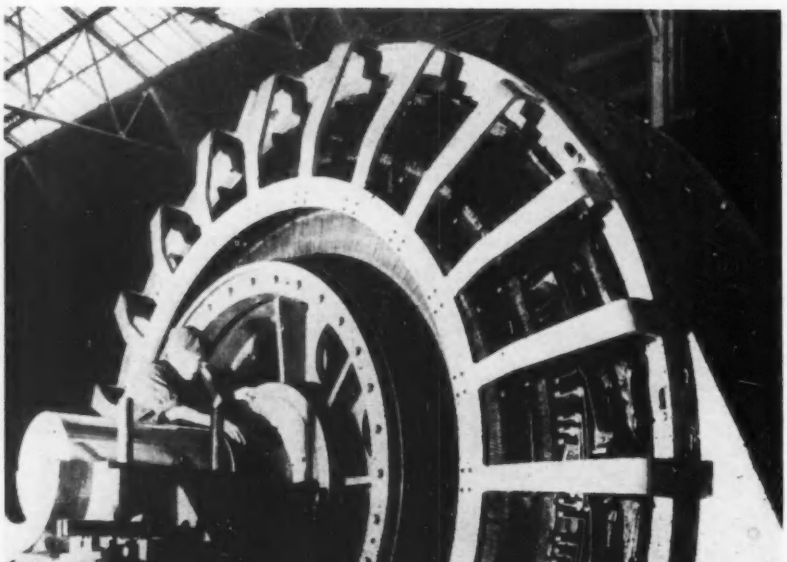
For this reason and other factors he pointed out that the components for electronics equipment used in military aircraft and other weapons of war, "must be designed to serve without replacement during the entire life of the equipment."

"Reliability" in airborne electronic equipment was stressed by Charles R. Banks of Aeronautical Radio, Inc. He indicated the magnitude of the electronic component reliability problem in airborne service by the following data:

"The airlines now have two million condensers, one and one half million resistors, and 180 thousand electron tubes operating in the electronic equipment of 750 aircraft. During the year of 1949, United Air Lines report on five thousand unscheduled equipment removals shows that 45 percent of the equipment irregularities were due to vacuum tubes. Of these units so removed, 20 percent were operating satisfactorily, 8 percent were removed because of sub-assembly troubles, 50 percent were incorrectly adjusted and required calibration, and 4 percent had defective condensers. Another three percent of these removals were caused by relays, and still another 3 percent by the tube sockets. Tuning controls, switches, crystals, wiring, and resistors, each amounted to one or more percent of the cause for the unscheduled removal of the electronic equipment from the airplanes. American Airlines has compiled a summary of electronic component failures on one type of airborne equipment; namely, the VOR or VFH omnirange receiver, which is the first airborne unit of the RTCA transition system. This summary shows that, of the unscheduled removals of the receiver, 49 percent were due to electron tubes, 16 percent were caused by defective audio transformers and reactors, 12 percent by relays, 12 percent by resistors, and 9 percent by defective condensers. The data on the types of electronic component failures was recently taken on 50 unscheduled removals from 120 airplanes. The normal aircraft electronic equipment service period is ninety days, which represents approximately 750 hours of flight time."

Leon Pododsky of Sprague Electric Company told the conference that designers are not making use of some presently available quality components. Too much pressure is being placed on miniturization tubes, and on reduced costs of equipment which in turn discourages the use of high quality components, he stated.

At the panel discussion which closed the 3-day session, Ernst Weber, Polytechnic Institute of Brooklyn, N. Y., called for closer teamwork between industry, military establishments and the ultimate consumers.

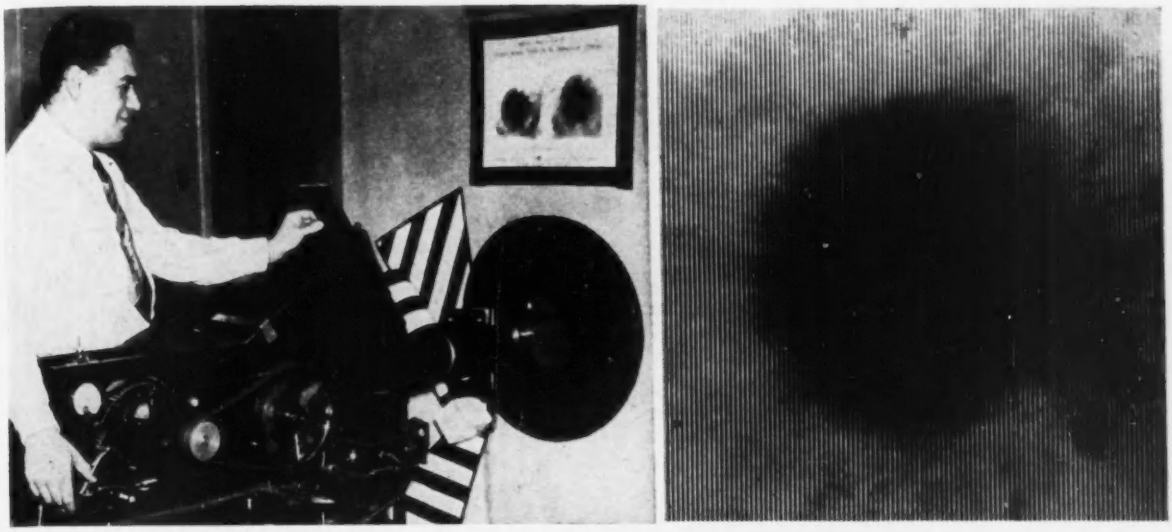


G.E. Builds Nation's Largest Mine Hoist Motor

THE LARGEST MINE HOIST MOTOR in the country from the standpoint of physical size has been shipped by General Electric's Large Motor and Generator Div. to the Anaconda Copper Mining Co. at Butte, Montana.

The giant 600-v d-c motor, rated 3,000 hp at 60 rpm, will drive an ore hoist at the Kelley Shaft, an important part of Anaconda's 20 million dollar "Greater Butte Project" for the recovery of low-grade copper ore by the caving method. When installed, the motor will be direct connected to the hoist drums.

The electric drive, GE engineers said, will be able to hoist 12 tons of ore per trip at a rate of almost half-a-mile a minute. Operating at full speed, it will be able to complete a trip from a depth of 4,335 ft in slightly more than two minutes.



MORTON SULTANOFF, civilian employee at the Army Ordnance department's Aberdeen Proving Ground, Md., displays his new camera. It takes pictures in 1/100,000,000 of a sec, and will be used to photograph high explosive shock waves. (Right) Shock wave leaving a spherical charge. Both black and white and color pictures have been taken at the speed of 10 billion a second.

New Camera Takes 10 Billion Pictures a Second

A DEVICE USED FOR MAKING PHOTOGRAPHS at the terrific rate of 100,000,000 frames per second has been developed by an Army technician at the Aberdeen Proving Ground, Maryland. The device makes photographs about 10 times faster than any previously made for industrial studies.

The Army is using the equipment for recording shock and detonation waves in the study of explosives. These waves move at a velocity of 8,000 meters per second, or roughly 18,000 miles per hour.

Designer Morton Sultanoff obtains the ultra speed in his device by the use of a framing grid and rotating mirror. The framing grid is a focal plane shutter which consists of a series of parallel, narrow, optically clear slits cut at uniform intervals through an opaque plate. The width of the slit determines the exposure time and the ratio of space width to slit width determines the number of successive independent frames. The resolving power, in lines per inch, is actually the number of slits per inch.

A rotating mirror sweeps a full size image of the grid across a 4 x 5 inch film plate and the total distance the image has to move to expose the entire film is merely one space width.

To obtain a detonation record, a first image of the phenomena is formed on the grid, and the image combination is moved across the film by the rotating mirror. The resulting picture is unintelligible unless reviewed through the grid. The original grid was made by the Mac Levy Photo Lithograph Company, Wayne Junction, Philadelphia, Pa.

It has long been necessary to know how to employ explosives in shaped charges and war heads, particularly guided missiles. Most of current equipment for this purpose is inadequate. Sultanoff explains that an explosion has a definite well ordered pattern from detonation to shock and although this is only a period of microseconds, the velocities of these phenomena are ¼ inch in 1 millionth of a second. The new camera was designed to study this high velocity.

Since the camera is not to be used as a motion picture camera its design and construction have the simplest possible optical and mechanical features. It costs less than $500, and was built from odds and ends and scrap equipment available at the Aberdeen ballistics laboratory.

The camera will materially aid in the future design and development of weapons of war, and may also be put to peacetime uses for the study of detonation knock in engines.

Machine Control Unit Simplifies Tool Changes

DESIGNED TO REDUCE INDIRECT LABOR COSTS, a "Machine Control Unit", made by the Cross Co., Detroit, Mich., reduces the time needed to make tool changes, reduces scrap, and simplifies tool grinding.

When a machine uses as many as 83 cutting tools the burden upon the operator can only be relieved by providing mechanical means to keep account of tools and to speed changing operations.

Basic components of the Cross Machine Control Unit are a master control board, a master tool setting fixture, a work bench, and Cross "Toolometers" which automatically shut down the machine when tools need changing.

The control board is divided into sections for each type of tool in the machine. Every section comprises a tool setting gage, a tag with the perishable tool and holder numbers, storage space for two complete sets of tools and holders, and a Toolometer. Alphabetical letters on the board and corresponding ones on the machine heads further group the tools and guide the operator. Colored areas on the control board point out the location of the machine head—yellow indicates a right hand horizontal head, red a left hand horizontal head and blue a vertical head. The tags with the perishable tool numbers provide

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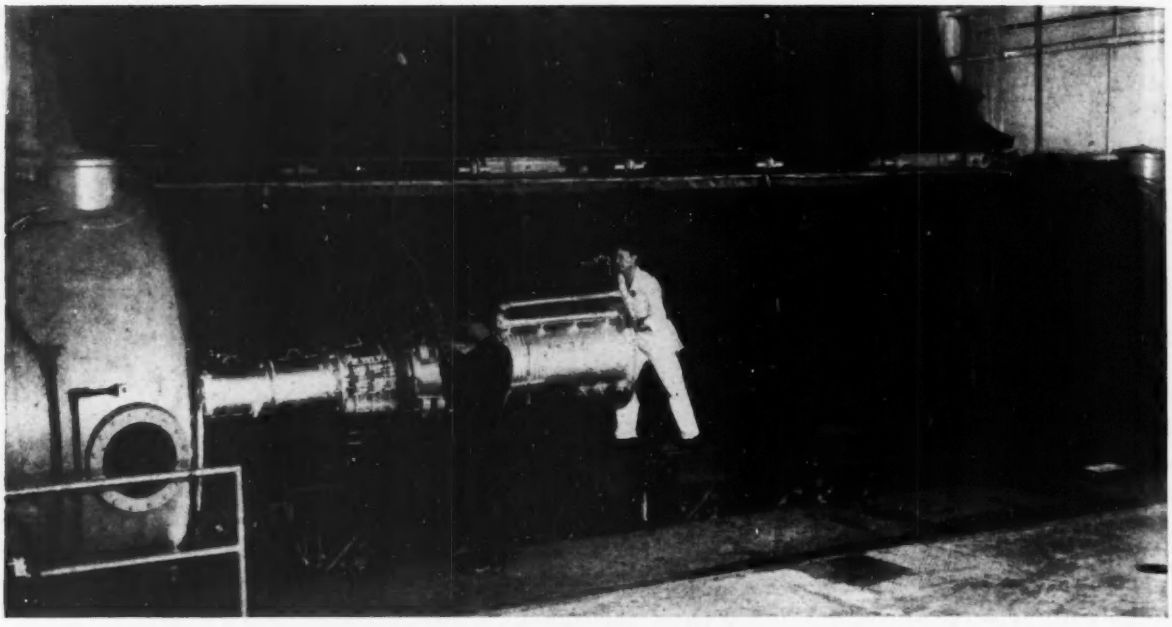

Ramjet Test Chamber Simulates 20 Mile Altitude

IN THE ABOVE PHOTO a large-scale ramjet engine is being lowered into position for a test run in the newly constructed high-altitude test chamber at the Ordnance Aerophysics Laboratory, Daingerfield, Texas. The laboratory is operated for the Navy Bureau of Ordnance by Consolidated Vultee Aircraft Corporation, under technical direction of The Johns Hopkins University Applied Physics Laboratory.

The Navy Bureau of Ordnance has disclosed that this new chamber enables engineers to test, for the first time in America's missile research program, large-scale ramjet engines at simulated altitudes of approximately 20 miles above the earth and at four times the speed of sound. The cylindrical test chamber is 10 feet in diameter and 125 ft long, with a door in its side 30 ft long through which ramjet engines are installed for tests.

When a ramjet is being tested, a high-pressure air supply feeds the inlet end of the chamber and a steam jet ejector system removes the air at the outlet. The vacuum system combines steam-jet ejectors with turbo blowers to obtain maximum capacity from a steam supply of 270,000 pounds per hour at a pressure of 400 pounds per square inch. By way of comparison, this quantity of steam would supply electricity for a city of 100,000 persons.

A cooling system provides 30,000 gallons of water per minute to the barometric condensers between the ejectors and blowers and to the ramjet exhaust cooling chamber.

For the past five years, the Ordnance Aerophysics Laboratory has been operating sea level ramjet test chambers and a supersonic wind tunnel to obtain basic data for the guided missile research program.

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the operator with on-the-job information for requisitioning worn parts.

Toolometers provide visual records of the used and unused life of every type of tool in the machine. Pointers on the Toolometers index counter clockwise with every machine cycle. When any one of the pointers reaches zero, the machine stops automatically. Red areas on the Toolometer dials, adjacent to the zero marks, represent "danger zones" for the last two hours or other appropriate period of productive tool life. When one of the Toolometers stops the machine, all tools in the "danger" zone are replaced. The Toolometers are then reset manually. The stops are adjustable to provide different settings for various types of tools and amounts of work.

Novel Drive Powers Swiss Bus

SWITZERLAND—What was described as the first "Gyro-Bus" in the world was shown here at the Swiss Industries Fair. It looks like a bus; the prototype has a capacity of 26 seated, 26 standing passengers. Interest in it centers around the fact that it has electrical flywheel drive. The vehicle is currently undergoing test runs on the road and will subsequently be put into regular service between the village of Altdorf and its railroad station on the Gotthard line.

The flywheel, weighing 1½ tons, runs in a casing in a rarified atmosphere of hydrogen and carries the rotor with a squirrel-cage winding. Before each trip, the flywheel is accelerated to 3,000 rpm by connecting the motor to the usual 50 cycle three-phase current. The mechanical energy of the flywheel is enough to carry the vehicle for about four miles before a one-minute stop is necessary to recharge it again. The vehicle is driven by a three-phase motor and various speeds are attained by changing the number of poles. During the trip the motor on the flywheel acts as a generator excited by condensers.

The Ateliers de Construction Oerlikon developed the gyro principle and tried it out for two years with a "gyrotractor" effecting the shunting operations on its premises. Great economy is claimed for the Gyro-Bus.

since no overhead lines or special substations are necessary. Other uses being considered are in ferry boats, mining locomotives, and coaches on railroad side lines.

CCNY Offers New Sales Engineering Course

A NEW INTENSIVE PROGRAM designed to meet the heavy current demand for trained sales engineers has been prepared for presentation this summer by the City College of New York Midtown Business Center and an Advisory Board of nine industrial leaders. Totalling 300 hours of instruction, and available in either 15-week daytime or 25-week evening courses, the Salesmanship for Engineers program will stress sales techniques and include no technical engineering material. Jack S. Schiff, supervisor of the school's salesmanship unit, now the world's largest sales training center, will be in charge of the new program.

The City College action has been hailed in business circles. George S. Jones, Jr., vice president and assistant to the president of Servel, Inc., and chairman of the National Distribution Council, said, "For years there has been a dearth of salesmen who can speak the language of industrial buyers. This idea of making salesmen of engineers, rather than trying to make engineers out of present salesmen should go a long way toward solving the problem. This program could well become one of the year's great benefits to industrial concerns."

The new program is designed to give engineers and others with a suitable technical background "controlled selling experience" which would normally take years of business experience to acquire. A total of 150 hours—half the course—will be devoted to such sales skills as the approach, the demonstration, meeting objections, handling the interview, and closing the sale. The largest portion of the remainder, 60 hours, is given over to practicing correct speech in selling.

Reheat Burner Adds Thrust to Jet

BUILT BY the Aircraft Gas Turbine Div. of General Electric, a new "reheat" burner adds extra power to jet engines by burning extra fuel in the tailpipe.

The device is added as an extra section on the standard G-E J-47 engine. It has been test flown in the North American F-95A, a higher-flying and extensively modified version of the F-86 jet fighter which holds the official world's speed record of 670.-981 miles per hour. Another experimental reheat power plant has also been testflown in the Republic XF-91. It was jointly sponsored by Republic Aviation designer and builder of the aircraft, NACA and General Electric.

RECENTLY ELECTED BY THE AMERICAN FOUNDRYMEN'S SOCIETY, Walton L. Woody is National President of the society for 1950-51, and Walter L. Sulbach National Vice-President. Mr. Woody holds the position of vice-president of National Malleable & Steel Casting Co., Cleveland, Ohio. Mr. Sulbach is president and general manager of Superior Foundry, Inc., also of Cleveland.

CHICAGO will have a complete "package design center" early this summer. Owned and operated by Dicken's, Inc., an industrial design firm, the center will cost more than $150,000, and is described as the world's first.

•

NEARLY TEN PERCENT OF ALL PACKARD EMPLOYEES are working on the Ultramatic Drive. Two shifts are needed to meet the strong demand.

•

WESTINGHOUSE has developed a new electrical insulation said to have a life at least 10 times as great as previous insulations. The new material will make possible construction of bigger generators.

•

THE THIRD SYMPOSIUM ON PLASTICITY will be held at Brown Univ., Providence, R. I. on Sept. 8 and 9. It will be sponsored by the Graduate Div. of Applied Mathematics. Interested persons should contact Professor D. C. Drucker at Brown University.

•

NATURAL RUBBER will be "grown to specification" in an attempt to compete with synthetics, according to the French International Rubber Research Board. Rubbers will be graded according to rate of cure, and plasticity.

•

THE LARGEST GLASS TELEVISION MIRRORS ever mass produced are currently being made by American Optical Co. The 26 in. 90 lb spherical mirrors are for use in projection-type theatre television. Projected pictures are expected to be as large as 15 by 20 feet.

•

FIRST U. S. INTERNATIONAL TRADE FAIR will be held in Chicago from August 7 through 20 of this year. Industrial machinery, engines, hand tools and measuring equipment from a dozen nations will be displayed.

•

A "KEY" TO UNPUBLISHED PATENT APPLICATIONS filed with the German Patent Office has been issued. Free booklets are available from the Office of Technical Services, Dept. of Commerce, Washington, D. C.

•

THE AIR FORCE will build a jet-engine test plant at Camp Forrest, Tenn. Nucleus of the new installation will be testing equipment worth $13-million brought over from Germany.

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Silicone News
DC
SILICONES
Dow Corning Silicone Insulation Saves Over $8,000 a Year on 4 Motors!
In the Saginaw Plant of Eaton Manufacturing Co., the output of four of these machines is stepped-up by stopping the 5 h. p., 3600 r.p.m. motors with a jolt of direct current as soon as 5 operations are performed on a small automotive part. With 105 starts and stops per hour, Class A insulated motors had an average life of only 8 days—32 failures for each of the 4 motors or a potential $10,000 a year in rewind costs alone.
Rewound with Dow Corning Silicone (Class H) Insulation, these motors now have a minimum life of 6 months; save Eaton a potential $8,000 a year plus a few hundred man hours of labor and some 40,000 parts that would have been lost due to down time.
DOWN TIME AND LOST PRODUCTION DUE TO MOTOR FAILURE ARE NO LONGER NECESSARY! Prove it in your own plant by having your hardest working motors rewound with Dow Corning Silicone Insulation. Call our nearest branch office for technical assistance or write to Dept. C-16.
Dow Corning Silicones Mean Business
DOW CORNING CORPORATION
MIDLAND, MICHIGAN
Atlanta • Chicago • Cleveland • Dallas
Los Angeles • New York
In Canada: Fiberglas Canada, Ltd., Toronto
In Great Britain: Albright and Wilson, Ltd., London
FIRST in Silicones
Dow Corning

Among engineering materials the performance of *Dow Corning Silicones* sounds as fabulous as the tall tales told of Paul Bunyan or Mike Fink who claimed to be half-man, half-alligator . . .

The tall tales of the old frontier are reflected in skyscrapers . . . jet planes that disappear before you hear them . . . materials that are half inorganic, half organic. Fact has become more fabulous than folk tales. Here are a few of the fabulous facts about Dow Corning Silicones:

- DC Silicone (Class H) Insulation has at least 10 times the life of the best electrical insulating materials previously available. It also increases the power per pound ratio of electrical equipment by 100%.
- DC 44 Silicone Grease has at least 10 times the life of organic greases.
- Silastic*, the Dow Corning Silicone rubber, is serviceable at temperatures from −100 to +500° F.—an impossible assignment for any other kind of rubber.

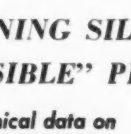
The consumer is shopping for quality at a price. Management demands longer life, increased production and lower maintenance costs.

YOU NEED DOW CORNING SILICONES TO MAKE THE "IMPOSSIBLE" PRACTICAL

Write today for technical data on

DC SILICONE GREASES

Including relative bleed, evaporation and oxidation resistance of Silicone and organic greases, penetrometer, solidification and flash points; performance and application data.



DC SILICONE (CLASS H) INSULATION

Including results of accelerated life testing of Silicone (Class H) and Class B insulated motors; service life data on rewound equipment; and data on performance of equipment designed to capitalize on exceptional heat and moisture resistance.

*T. M. Reg. U. S. Pat. Off.

DOW CORNING CORPORATION, MIDLAND, MICHIGAN
Please send me ☐ Grease data sheet No. X-18.
☐ Silicone Insulation data sheet No. X-18A.

Name_____
Title_____
Company_____
City_____ Zone____ State_____

DOW CORNING CORPORATION, MIDLAND, MICHIGAN
Atlanta • Dallas • Chicago • Cleveland • Los Angeles • New York
In Canada: Fiberglas Canada Ltd., Toronto • In Great Britain: Albright and Wilson, Ltd., London

General Properties of Plastic Materials

WYMAN GOSS, CHEMICAL DEPARTMENT, GENERAL ELECTRIC COMPANY

THERMOSETTING MOLDING COMPOUNDS

Applications	Resin Type	Filler	Colors	Impact ft-lb per in. notch	Flexural psi	Tensile psi	Water Absorption percent, 48 hr	Heat Resistance, continuous, deg F	Dielectric Strength volts per mil, step by step, test in oil, 1/8 in. specimen		Specific Gravity	Shrinkage in. per in. *	Bulk Factor **
									25 C	100 C			
For general purpose molding applications.	Phenolic	Woodflour	Most colors, and mottles except pastes	0.032	11,000	7500	0.8	248	325	70	1.38	0.007	3
For general purpose high-dielectric applications.	Phenolic	Woodflour	Natural	0.28	10,000	7500	0.8	248	300	100	1.34	0.008	3
Parts requiring good water resistance and minimum odor.	Phenolic	Woodflour	Black	0.30	9000	5500	1.0	248	150	40	1.36	0.005	3
For bearings, cams, slides, caster wheels, etc. requiring reduced friction.	Phenolic	Woodflour and Graphite	Gun Metal	0.32	8000	6000	0.8	248	....	....	1.39	0.007	3
For heater plugs and insulating pieces requiring good heat resistance.	Phenolic	Asbestos and Woodflour	Most colors, except pastels	0.30	10,000	6000	0.5	285	200	50	1.67	0.004	3
For parts requiring better heat resistance and for low power arc resistance.	Phenolic	Short Fibre Asbestos	Black, Brown, and Red	0.30	9000–10,000	6000	0.1	300	200	50	1.80	0.003	3
Best phenolic for heat resistance, low moisture absorption, low coefficient of expansion and max. dimensional stability.	Phenolic	Long Fibre Asbestos	Black, Brown, and Natural	1.2	10,000	5000	0.06	300	100	30	1.90	0.001	6
Combines high impact resistance with improved flame resistance.	Phenolic	Asbestos Fabric	Natural	3.5	11,000	6200	0.8	300	135	35	1.65	0.003	5
Combines high impact resistance with improved flame resistance and moldability.	Phenolic	Asbestos Fabric	Natural	2.24	10,000	7000	0.8	300	135	35	1.65	0.002	5
For bearings, slides, valves, cams, etc. requiring max. heat-resistance and dimensional-stability with good wear resistance.	Phenolic	Asbestos and Graphite	Gun Metal	0.28	8000	5000	0.06	300	....	....	1.82	0.003	3
Best phenolic for heat resistance and minimum flammability with low bulk factor for intricate molding.	Phenolic	Asbestos	Black, Brown, Red	0.40	9000	5000	0.01	300	250	50	1.83	0.002	3
Electrical applications requiring improved heat and low-moisture absorption.	Phenolic	Mica	Natural and Black	0.40	11,000	6000	0.05	300	300	170	2.08	0.001	3
A general purpose molding material with improved impact resistance.	Phenolic	Cotton Flock	Black and Brown	0.60	10,500	6500	0.8	248	250	50	1.37	0.003	4
A medium-high impact material with good flow for complex sections.	Phenolic	Fabric—Short Fibre	Natural, Black, Red, Brown	1.20	10,500	6200	1.0	248	250	50	1.39	0.002	5
A high-impact material generally used for bulky sections.	Phenolic	Fabric—Medium Fibre	Black, Brown, Red	3.2	10,000	6300	1.0	248	225	35	1.40	0.002	8
For cams, bearings, slides—parts requiring high impact and reduced friction.	Phenolic	Fabric and Graphite	Gun Metal	0.70	8000	6000	1.0	248	....	....	1.45	0.004	4
For cams, bearings, slides, etc. requiring medium-impact resistance and reduced friction.	Phenolic	Cotton Flock and Graphite	Gun Metal	0.40	9500	6000	1.0	248	....	....	1.41	0.002	4

Footnotes on page 153

(continued on page 151)

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What an Appliance Maker learned from an Automotive Specialist about DIE CASTING...

BUILDING appliances was an old story to a well-known manufacturer but he knew the reputation of the automotive industry for getting quality products at low cost. He figured that any firm with the know-how to serve the car-making industry might be able to show him ways to improve quality and save money doing it. So when a rather unusual die casting and plating requirement came up, he got in touch with the Auto-Lite Die Casting Division. The result was an improved casting and a saving in money, too.

If you have a die casting requirement in which quality or price is a problem, or if you need the help of Auto-Lite's famous design and engineering experts, write to

THE ELECTRIC AUTO-LITE COMPANY
Die Casting Division
• • •
Woodstock, Illinois
600 So. Michigan Ave., Chicago 5, Illinois
Lockland, Ohio
723 New Center Bldg., Detroit 2, Michigan

AUTO-LITE

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plastics
wire and cable
industrial
thermometers

THERMOSETTING MOLDING COMPOUNDS (CONTINUED)

Applications	Resin Type	Filler	Colors	Impact ft-lb per in. notch	Flexural psi	Tensile psi	Water Absorption percent, 48 hr	Heat Resistance, continuous, deg F	Dielectric Strength volts per mil, step by step, test in oil, 1/8 in. specimen		Specific Gravity	Shrinkage in. per in. *	Bulk Factor **
									25 C	100 C			
Radio or similar parts requiring low dielectric losses. P.F. @ 1000 kc, 0.009.	Phenolic-aniline	Mineral	Natural	0.35	9500	6000	0.05	248	350	375	1.90	0.004	3
General purpose color work. Has good arc resistance. Used for lamp shades, packages, radio cabinets, etc.	Urea	Cellulose	All colors including translucent and pastel shades	0.25	11,000	6300	1.5	170	240	80	1.48	0.008	3
Material has good arc and flame resistance with medium mechanical strength. Good resistance to water and food stain.	Melamine	Fabric	Natural, white, black and some colors	0.90	10,000	6000	0.5	248	225	90	1.49	0.004	12
General purpose color work with improved-temperature resistance. Good for dishes and buttons.	Melamine	Cellulose	All colors including translucent and pastel shades	0.30	13,000	8000	1.0	176	240	150	1.45	0.007	3
Hycar*** modified phenolic. Appearance and moldability similar to general purpose phenolics with toughness and resilience of cotton flock and rag filled materials.	Hycar-Phenolic	Woodflour	Black	0.60	7000	4500	2.5	212	250	80	1.31	9	3.5
Hycar*** modified phenolic. Appearance and moldability similar to flock filled phenolics. Has shock resistance about 5 times that of flock filled phenolic.	Hycar-Phenolic	Cotton flock	Black	1.00	8000	4500	2.5	212	224	50	1.33	4.5	4
Hycar*** modified phenolic. Appearance and moldability similar to fabric filled phenolics. Used for extreme physical and thermal shock resistance.	Hycar-Phenolic	Chopped Fabric	Black	2.30	7000	3500	2.1	212	200	60	1.32	4.5	8
Hycar*** modified phenolic. Appearance and moldability similar to asbestos filled phenolics. Used for heat resistance parts subject to physical and thermal shock.	Hycar-Phenolic	Asbestos	Black	0.40	7000	4000	0.40	257	300	60	1.63	6.5	2.5

THERMOPLASTIC MOLDING COMPOUNDS

General purpose injection molding material. Uses limited by low softening point and moisture absorption.	Cellulose acetate		All colors, transparent, translucent and opaque.	1.6	9000	6000	3.0	140	275	....	1.32	0.003	2
General purpose injection and extrusion material with better resistance to distortion under heat and humidity.	Cellulose acetate butyrate		All colors, transparent, translucent and opaque	2.0	8000	5000	1.5	140	275	....	1.22	0.003	2
Products requiring good strength at low temperatures, water resistance, toughness, weather resistance, dimensional stability.	Ethyl cellulose		All colors, transparent, translucent and opaque	3.0	9500	6000	1.4	150	500	....	1.14	0.004	2
For parts requiring good electrical properties, resistance for chemicals. Has low density, zero moisture absorption.	Polystyrene		All colors, transparent, translucent and opaque	0.30	9000	5500	0.05	158	550	....	1.06	0.002	2
Extruded for chemical and water resistant tubing. Injection molded for chemical equipment, plating racks and valve parts.	Vinylidine chloride (Saran)		Translucent, amber and opaque colors	5.0	16,000	6000	0.1	160	350	....	1.70	0.010	2
Excellent transparency and optical properties, low gravity, fair chemical resistance. Used for lenses, decorative parts, nameplates, packages, etc.	Methyl methacrylate		All colors, transparent, and translucent	0.4	15,000	8000	0.5	140	400	....	1.18	0.005	2

Footnotes on page 153

(continued on page 153)

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Name the shape you want

Chances are good we can supply Armco Steel Mechanical Tubing in any shape you require.

Getting made-to-order shapes of this light-walled steel tubing can help you eliminate or greatly reduce many costly fabricating operations. It also helps step up production.

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This means lightweight, high-strength products at low cost. Armco Steel Mechanical Tubing is pleasing to the eye, too . . . helps you design products that are more saleable.

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THERMOPLASTIC MOLDING COMPOUNDS (CONTINUED)

Applications	Resin Type	Filler	Colors	Impact ft-lb per in. notch	Flexural psi	Tensile psi	Water Absorption percent, 48 hr	Heat Resistance, continuous, deg F	Dielectric Strength volts per mil, step by step, test in oil, 1/8 in. specimen		Specific Gravity	Shrinkage in. per in. *	Bulk Factor **
									25 C	100 C			
Injection molded and extruded bearings and gears.	Nylon		Unlimited, except clear	3.0	13,000	9000	7.0	200	400	....	1.14	.....	2
Minimum cold flow at room temperature, good water, chemical, impact resistance, non-inflammable. Some forms used as rubber substitute.	Copolymer vinyl chloride and vinyl acetate		All colors, except a water white	0.8	13,000	9000	0.1	130	380	....	1.35	0.002	2

* Shrinkage. Molding materials shrink after they are molded. The values listed in the table give the amount of this shrinkage in inches per inch under average conditions. Allowance must be made in the mold design to compensate for this shrinkage.

** Bulk factor. Mold designs must allow sufficient space for loading the molding compound. The ratio of the volume of compound before molding to the volume of the molded piece is called the bulk factor.

*** Registered trade name of B. F. Goodrich Chemical Company for nitrile-type synthetic rubber.

THERMOSETTING PLASTIC LAMINATES

Applications	NEMA Type	Dielectric Strength volts per mil, 25 C, short time in oil	Power Factor 1 megacycle *	Dielectric Constant 1 megacycle *	Moisture Absorption 24 hr percent	Specific Gravity	Flexural Strength psi **	Tensile Strength psi **	Compressive Strength psi **	Izod Impact ft-lb per in. notch ***
Mechanically strong, fair electrically, machines readily, but not punchable—low priced. Phenolic resin, paper base.	Grade X	700, perpendicular to laminations 48 kv/in., breakdown parallel to laminations	0.050, Dry 0.056, Wet	6.0, Dry 6.2, Wet	3.00, 1/16 in. 1.70, 1/8 in.	1.40	21,000 L 22,200 C	20,000 L 15,000 C	35,000, F 21,000, E	2.5, F 1.0, E
Best purpose general grade, good electrically and mechanically, machines and hot punches readily. Phenolic resin, paper base.	Grade XX	800, perpendicular 60 kv/in., breakdown parallel to laminations	0.040, Dry 0.042, Wet	5.0, Dry 5.4, Wet	1.80, 1/16 in. 1.10, 1/8 in.	1.35	16,000 L 15,000 C	16,000 L 12,000 C	35,000, F 18,000, E	3.5, F 0.5, E
Best grade electrically, machines well. Has excellent dimensional stability. Phenolic resin, paper base.	Grade XXX	750, perpendicular 50 kv/in., breakdown parallel to laminations	0.034, Dry 0.036, Wet	5.0, Dry 5.5, Wet	1.00, 1/16 in. 0.85, 1/8 in.	1.35	19,000 L 18,000 C	12,000 L 10,000 C	32,000, F 20,000, E	2.7, F 1.3, E
High toughness, fair electrically, machines and punches excellently. Phenolic resin, fabric base.	Grade C	400, perpendicular 40 kv/in., breakdown parallel to laminations	0.055, Dry 0.080, Wet	5.0, Dry 5.8, Wet	1.60, 1/16 in. 1.30, 1/8 in.	1.35	20,000 L 18,000 C	10,000 L 9,000 C	38,600, F 23,000, E	5.8, F 2.8, E
Good electrically and mechanically. Has excellent dimensional stability and acid resistance. Phenolic resin, fabric base.	Grade CE	500, perpendicular 45 kv/in., breakdown parallel to laminations	0.045, Dry 0.050, Wet	5.2, Dry 5.6, Wet	1.50, 1/16 in. 1.20, 1/8 in	1.35	17,000 L 13,000 C	12,000 L 8,000 C	36,000, F 22,000, E	3.5, F 2.3, E
Best electrically of fabric base grades, good mechanically. Machines and punches excellently. Phenolic resin.	Grade LE	500, perpendicular 40 kv/in , breakdown parallel to laminations	0.045, Dry 0.050, Wet	5.0, Dry 5.5, Wet	2.00, 1/16 in. 1.40, 1/8 in.	1.34	19,000 L 17,000 C	14,000 L 9,500 C	37,000, F 23,000, E	4.8, F 2.0, E
Woven asbestos base, heat resistant to 150 C. Low dielectric strength, but excellent dimensional stability. Phenolic resin binder.	Grade AA	50, perpendicular 8 kv/in., breakdown parallel to laminations	0.600, Dry 0.750, Wet	7.5, Dry 12.5, Wet	1.90, 1/16 in. 0.90, 1/8 in.	1.67	20,000 L 16,000 C	9,000 L 8,000 C	38,000, F 20,000, E	4.8, F 4.4, E
Glass fabric base, heat resistant to 150 C with remarkable electrical and mechanical properties, especially when dry. Phenolic resin binder.		450, perpendicular 45 kv/in., breakdown parallel to laminations	0.017, Dry 0.140, Wet	4.8, Dry 5.5, Wet	2.24, 1/16 in. 2.00, 1/8 in.	1.76	30,500 L 38,100 C	28,000 L 22,000 C	68,000, F 17,000, E	Over 16.0, F Over 16.0, E
Glass fabric base, silicone resin. Heat resistant to 250 C, good mechanically, outstanding on electrical losses and power factor.		300, perpendicular 40 kv/in., breakdown parallel to laminations	0.0015, Dry 0.015, Wet	2.88, Dry 3.67, Wet	0.63, 1/8 in. 0.32, 1/2 in.	1.68	14,000 L 11,800 C	16,800 L 10,500 C	36,000, F 10,300, E	17.0, F 13.9, E

* Wet refers to the value obtained after immersion of the sample in water for 24 hours.

** L—Tested lengthwise to laminations.
C—Tested crosswise to laminations.

*** F—Tested on face of laminate.
E—Tested on edge of laminate.

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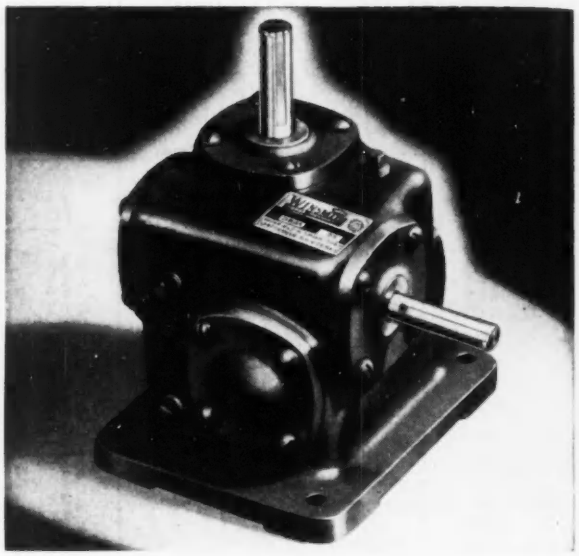
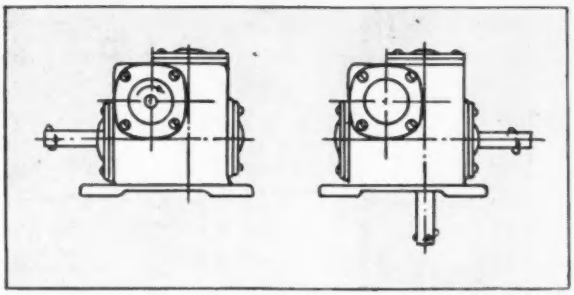
Double Worm Gear Reducers Give Standard Power Transmission For Applications Below ⅛ Hp





Right angle worm gear reduction is made available for a number of applications by this reducer, fully standardized and stocked in 24 different assemblies. A power range from 1/20 to ⅛ hp, and standard reduction ratios from 25:1 to 1746:1 are offered.

One standard body is used with 6 possible shaft positions. The line drawings at right show how the 24 standard variations in right-angle shaft positions are furnished. This flexibility extends mass production costs to transmission applications usually filled on special orders. Power can be channeled to either side, up, or down. The gear unit can also be driven from any direction.

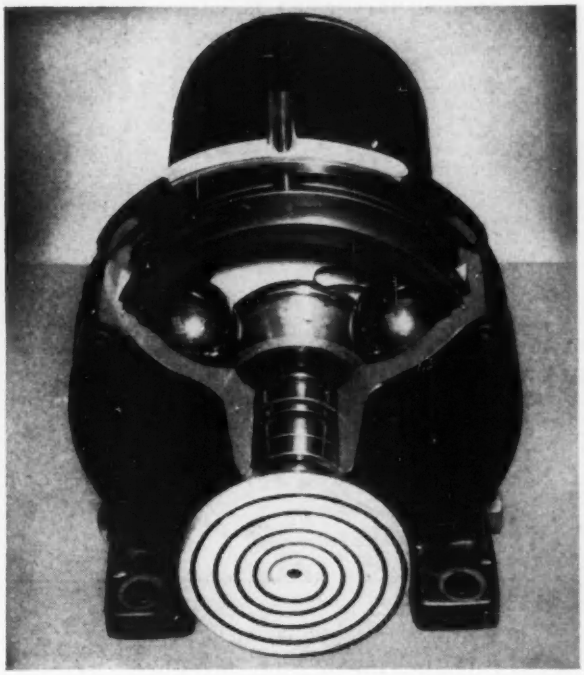
A single piece housing encloses a double set of integral shaft worms of case-hardened, ground and polished steel, mated with bronze worm gears. Tapered roller bearings are used throughout. Extra slow speeds are available as listed below, in any shaft arrangement. This range of standards is intended to allow the designer to engineer his speed reduction units to fit fractional hp jobs, instead of being forced to specially built or disportionately large capacity reducers.

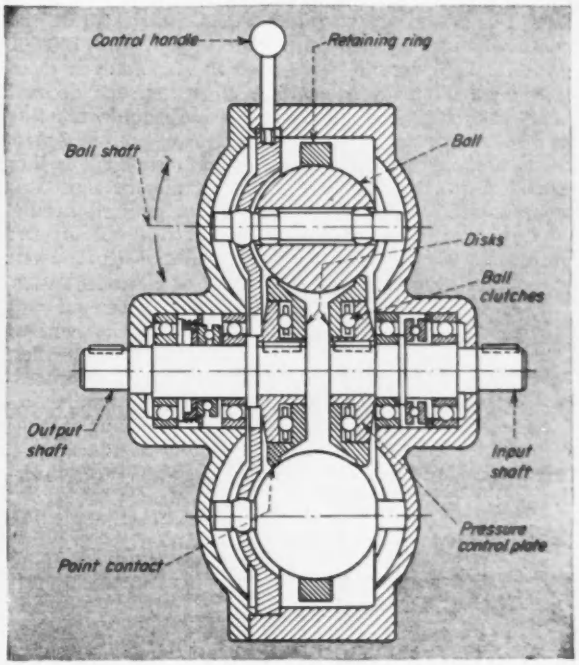
The base is 6½ by 5¼ in., and the body is 4⅞ in. high. A ⅝ in. shaft is used on the slow speed side, and a ½ in. shaft on the high speed. Shaft projections are 2 inches.

Winfield H. Smith Corp., Springville, N. Y.

Overall Ratio of Reduction	Primary Ratio	Secondary Ratio	Maximum Output Torque In-Lb	Allowable Shaft Loads		
				Overhung Load on Input or High Speed Shaft	Overhung Load on Output or Slow Speed Shaft	Thrust Load on Slow Speed Shaft (Down)
1764	42	42	101			
1260	42	30	151			
900	30	30	151			
840	42	20	168			
600	30	20	168			
420	42	10	163	90 Lb	120 Lb	216 Lb
400	20	20	168	at all	at all	at all
300	30	10	163	speeds	speeds	speeds
210	42	5	154	and	and	and
200	20	10	163	ratios	ratios	ratios
150	30	5	154			
100	10	10	163			
50	10	5	154			
25	5	5	154			

Circle No. 1 on Reader Service Card





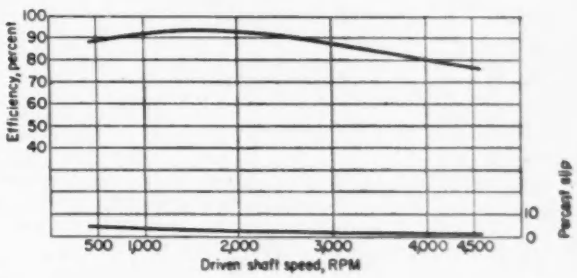
Variable Transmission With Ring of Balls

With an input of 1,500 rpm, any speed between 500 and 4,500 rpm is obtained from this drive unit. Power transmission is constant, efficiency is 90 percent and slip is 2 percent at high speeds. Capacities from ¼ to 12 hp are available.

Two hardened disks, one on the input and the other on the output shaft, impinge on three balls, held in a retaining ring in a plane perpendicular to the shafts. Point contact is made between balls and disks. Ball clutches hold the disks in contact with the balls through pressure control plates.

To vary the speed, a hand lever is moved in the plane of the sphere retaining ring. By cam action, this changes the angle between the ball rotating axis and the horizontal. A change in position of the rotating axes of the balls in turn changes the disk contact points in relation to these axes. The relative diameters (and hence, circumferences) of the ball contact circles is thus changed. In this way, the output speed is varied with constant input.

Driving disks, balls, and retaining rings are ball-bearing steel, hardened to 63 Rockwell. Castings are Meehanite. Balls are lapped to 0.00015 in. for roundness and concentricity. Years of service without measureable wear are claimed. Oil is changed at 1,000 hours.



Standard capacities from ¼ to 12 hp are available. Power output depends on input speed, which must be between 750 and 3,000 rpm. Models with integral motors or output shaft reduction gearing are available. A number of the units have been successfully used in European machine tools.

Allspeed Ltd., Oakenshaw Wks., Clayton-Le-Moors, Accrington, Lancaster, England

Circle No. 2 on Reader Service Card

CONTINUED ON PAGE 156

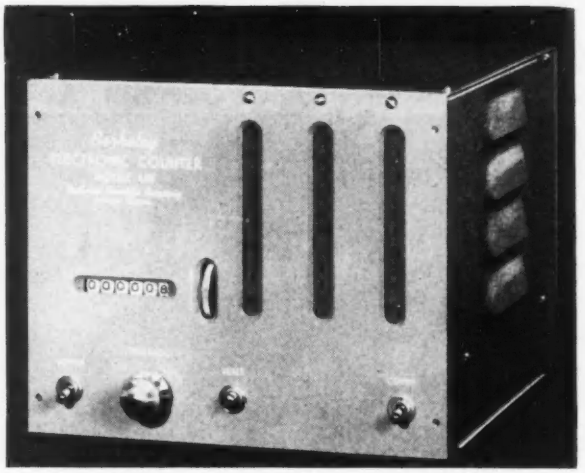
UNIVERSITY OF MICHIGAN LIBRARIES

Industrial Counter Registers 10,000 Units Per Second

A new direct-reading electronic counter capable of registering at rates up to 10,000 counts per second is now in production . The new unit will count any occurrence which can be made to actuate a mechanical, electrical or optical device. It registers each "pulse" or count regardless of fluctuations in occurrence rate, provided that the minimum time between any two counts is 2/100,000 second. The count in digits, tens and hundreds is registered on the illuminated panels of three electronic decimal counting units; output from the last electronic counting unit is sufficiently slow to be registered on a 6-place mechanical register. The range of the instrument is thus extended to 1,000,000,000. Counting may be started or stopped, and registers reset, either manually or electrically. The unit can be set to produce an electrical output after every 10, 100, or 1,000 counts to actuate a signal, divert a feed line or operate any mechanical or electrical device.

Used with a photocell and light source, the unit will provide an individual count of units moving on belts or chutes, count register marks on paper, fabrics or textiles, revolutions of high speed shafts, vibrations and movements, and similar occurrences. It can be used to determine frequencies up to 10,000 cycles per sec by providing a count of cycles for a definite period of 10 or 100 seconds.

The complete instrument is contained in a silver-hammertone finished steel cabinet measuring $7\frac{1}{4}$ x $9\frac{3}{8}$ x $10\frac{3}{16}$ in., weighing 16 lb. Power input required is 105-125v, 50-60 cycles a-c.



Berkeley Scientific Co., 6th and Nevin Ave., Richmond, Calif.

Circle No. 3 on Reader Service Card

Cylinder Valve Resists Corrosion

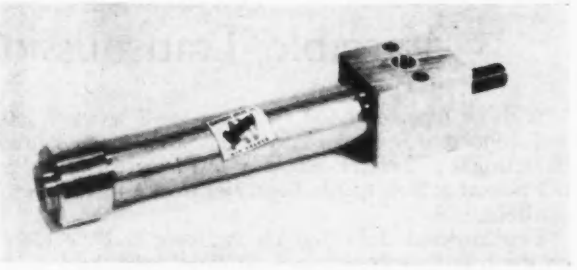
A new corrosion resistant air and hydraulic cylinder valve, fabricated from solid brass bar stock, and with a pressure range up to 1,500 psi is offered for air, oil or water service. These valves are energized by virtually any type of valve control.

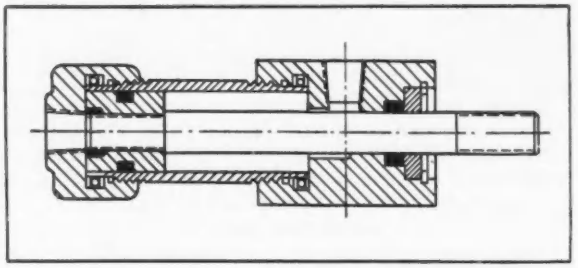
The new model is designed for such operations as light transfer, latching and tripping motions, as well as the usual raising, lowering, pushing and clamping operations. Tube connections are $\frac{1}{4}$ in. pipe thread. Universal mounting and adjustable length of stroke make additional applications possible.

Valve head, cap and mounting are claimed to be unbreakable. Proved, self-adjusting packings eliminate the possibility of damage due to improper hand adjustment, minimize leakage and assure long life.

Standard cylinders are drilled and counterbored for mounting either on the piston rod end, or for the usual mounting on the side or foot. They are furnished standard double acting. Single acting types with integral springs or other special types are available to specification.

The valves can be furnished with center swivel mounting studs, with flat ends tapped for mounting screws, or with projecting end eyelet for end-swivel attachment. Actuating rods are $\frac{1}{2}$ in. in diameter, threaded 1 in. from the end. Spherical rod ends are optional.





CYLINDER LENGTHS VARY from 3 to 3 3/8 in., plus the length of stroke. The difference lies in the type of end mounting or connection desired in each application. Double acting model shown. Spring-loaded, single acting cylinders are special.

Airmatic Valve Inc., 1643 E. 40th St., Cleveland, Ohio

Circle No. 4 on Reader Service Card

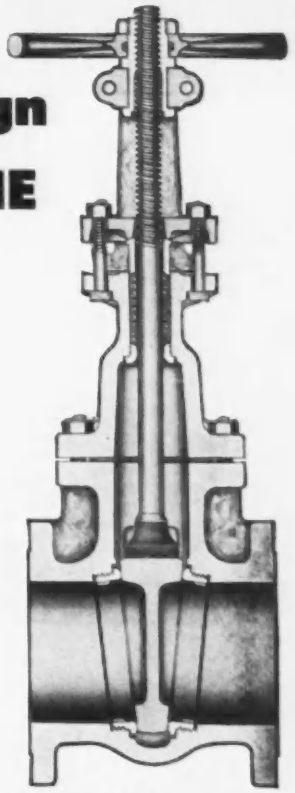
CONTINUED ON PAGE 158

Piping equipment for every design ...from one complete line...CRANE

When you design a **Fuel Oil Pumping and Heating Unit**, for example, your "specs" call for piping equipment that must control steam and heated fuel oil. Actually, however, it makes no difference what fluids you're concerned with . . . or what type of machine you're designing. If it's piping equipment you're after, all you have to do is turn to Crane.

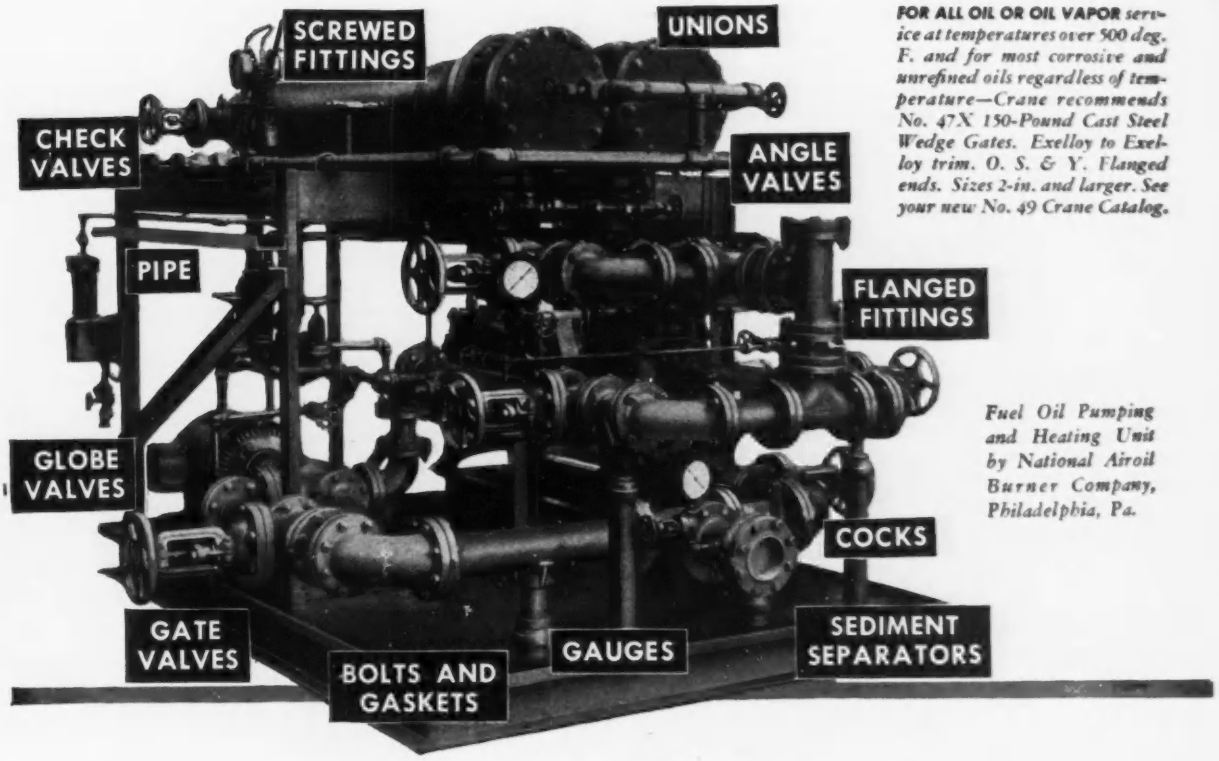
One catalog puts the world's most complete line of piping materials right in the palm of your hand. Specifying Crane as your single source of supply helps to speed and simplify all piping procedures, from drafting room to assembly lines. Also, specifying Crane gives your product added value. Machinery buyers know from experience that Crane Quality cannot be surpassed.

CRANE CO., 836 S. Michigan Ave., Chicago 5, Ill.
Branches and Wholesalers Serving All Industrial Areas



FOR ALL OIL OR OIL VAPOR *service at temperatures over 500 deg. F. and for most corrosive and unrefined oils regardless of temperature—Crane recommends No. 47X 150-Pound Cast Steel Wedge Gates. Exelloy to Exelloy trim. O. S. & Y. Flanged ends. Sizes 2-in. and larger. See your new No. 49 Crane Catalog.*

YOU NAME IT... CRANE SUPPLIES IT
EVERYTHING IN PIPING FOR YOUR DESIGN



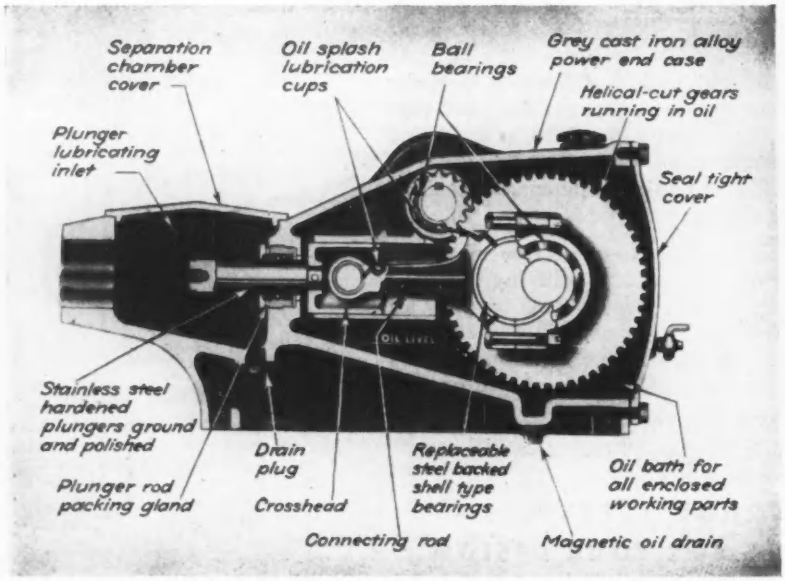
Fuel Oil Pumping and Heating Unit by National Airoil Burner Company, Philadelphia, Pa.

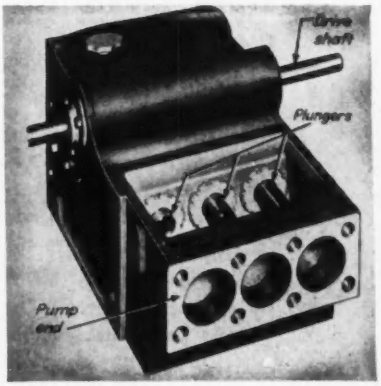
EVERYTHING FOR EVERY PIPING SYSTEM **CRANE**

VALVES • FITTINGS • PIPE • PLUMBING AND HEATING

UNIVERSITY OF MICHIGAN LIBRARIES

Power Ends Are Adopted to Specialty Pumps





Stroke, in.	Max. Crank Shaft Speed	Gear Ratio	Shipping Weight, Lb	Max. Torque on Shaft Ft-Lb
2¼	180 Rpm	3.60	350	125
2¾	174 Rpm	3.60	555	260
3¾	165 Rpm	4.06	900	485
5	150 Rpm	4.88	1750	1400

Reciprocating pumps can be designed for a wide variety of uses by adding pump heads to one of four power ends offered. The new units are built around an eccentric drive, supported on ball bearings and powered through a single helical gear reduction. Three operating plungers are employed to ensure balanced rotation.

The eccentric shaft is a one-piece drop forging, with electrically hardened surfaces carrying the plunger shell bearings. The gear ring is drop-forged, with cut teeth. Oversized plunger guides are enclosed in a machined housing, included as an integral part of the pump case. Guides and crosshead pins are oil-bath lubricated.

The fluid end of the unit is designed by the purchaser to suit his needs. Any manifold and valve arrangement can be used. Pump plunger barrels and seals must of course be fitted to the existing power unit case. Overall length of the power-head varies from 22½ to 47 in., height from 11 to 23¾ in., and width from 10½ to 20½ inches.

John Bean Div., Food Machinery & Chemical Corp., Lansing, Mich.

Circle No. 5 on Reader Service Card

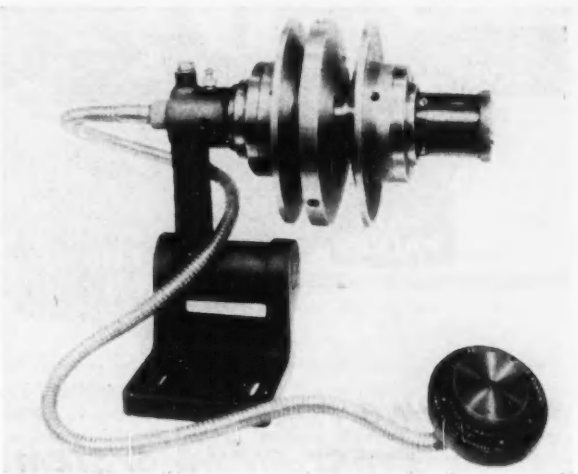
Intermediate Pulley Adjusts Drive Speeds

Stepless speed control is obtained with a new double groove pulley, set up between the drive and driven shafts. A V-belt in one groove connects to the drive shaft, while the other groove holds a V-belt to the driven shaft. An aluminum alloy pulley model has a 2:1 range on 1, 1½ and 2 hp drives. A smaller unit uses molded plastic sheaves, steel faced for wear, and covers a 3:1 range of speed variation on ¾ and 1 hp drives.

Control is accomplished by simultaneous variation of the pitch diameters of the two grooves while the drive is running. Changes are made by a shaft knob, or alternately by a remote-control indicator dial. The assembly is pivoted at the base and can be mounted in any position.

Spacing between sheaves is set mechanically and held firmly, regardless of belt wear, pull, or stretch. Positive sheave location is designed to minimize ratio slip under varying loads. All three sheaves move in the same ratio and no variations in belt alignment occur.

American Type Founders Corp., 200 Elmora Ave., Elizabeth, N. J.



Circle No. 6 on Reader Service Card

CONTINUED ON PAGE 160

THE RANGE INDUSTRY

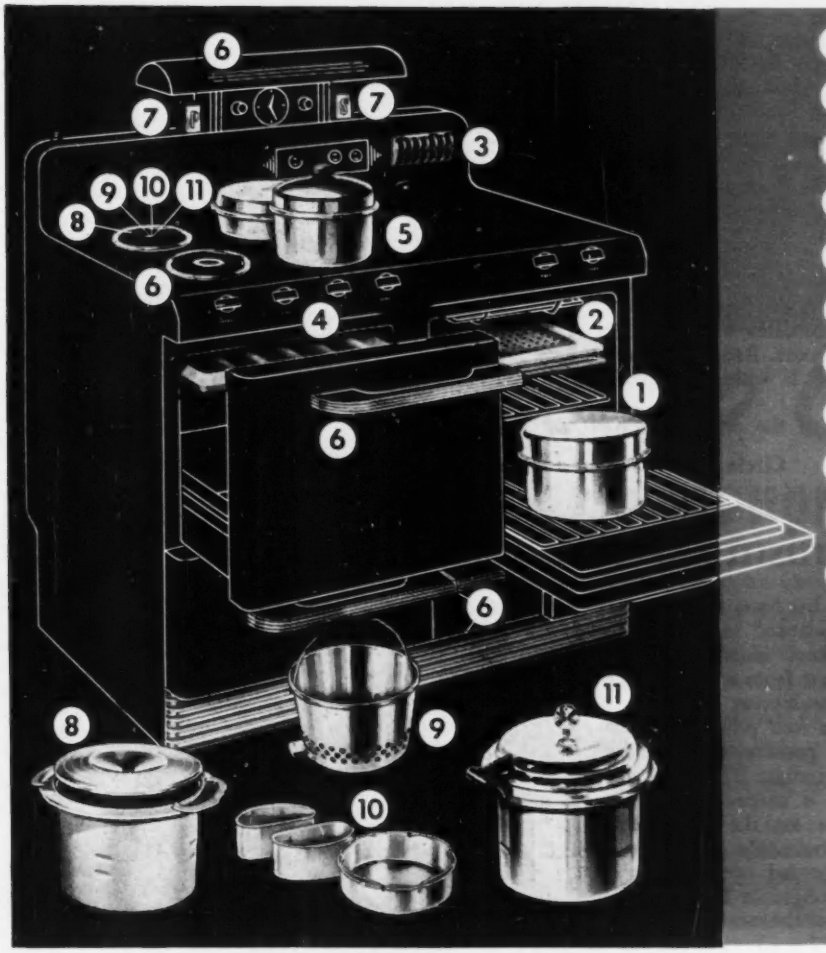
Aluminum is an essential metal in this important field of modern manufacturing. The illustration indicates some of the numerous aluminum parts that we produce for the nation's leading range makers. It is a phase of our contract activity that we have enjoyed for many years.

ONE OF THE MANY WE SERVE

WITH ALUMINUM PARTS

Whatever your product may be, if it requires aluminum parts, our diversified skills and facilities can produce them. Alloys and thicknesses? What are your needs? We custom roll sheet metal to your parts specifications, in our own modern rolling mill. Finishes? Satin, color, anodic, polished or chemically brightened. Engineering? Design? Our staffs are at your service.

Your inquiry will focus our full attention on *your* needs . . . at once.



1. Stacking Pans
2. Broilers
3. Louvres and Vent Grills
4. Drip Pans and Reflectors
5. Range Set Items
6. Decorative Trims
7. Salt and Pepper Shakers
8. Deep-Well Cookers
9. Deep-Well French Fryer
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Single Phase Changed to Three Phase Electronically

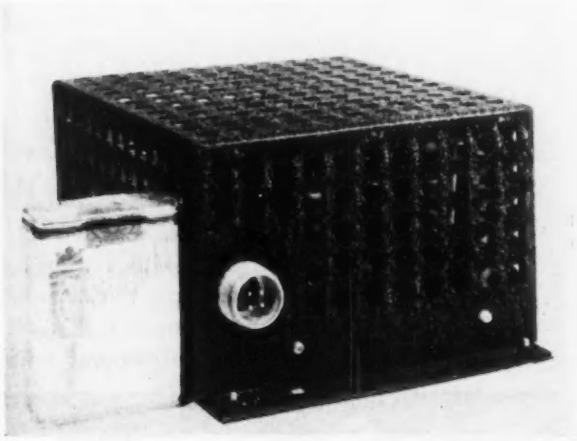
Announcement has been made of an electronic phase adapter, changing single phase 115 v, 400 cycle to three phase, 115 v at 100 va. Output voltage on all phases is equal to input voltage within 3 percent over a range of input voltages and frequencies, loads, power factors, temperatures and altitudes. There are no moving parts. Weight is 6¾ lb and volume 168 cubic inches.

The new device consists of a reactor and capacitor in series directly across the line, the third phase terminal being their common connection. The voltage across each leg is sensed by a bridge. Variations produce control currents which are applied separately to modify the reactance of each component. This maintains constant voltage, substantially equal to the input voltage, on each of the new output phases. This automatically maintains constant phase angles.

The phase adapter is built on an aluminum base. It is enclosed in a perforated aluminum case, finished in black wrinkle lacquer. Having no revolving or oscillating switches, commutators, rings, brushes, or bearings, it may be operated at any temperature from —55 C to +70 C and in any position. Condensers, resistors, vacuum tubes and standard parts are JAN wherever possible.

Initial warm up time is 25 seconds. A special time delay circuit prevents application of output voltages to load until the bridge control tubes have equalized the three output phase voltages.

This phase adapter has been designed for maximum resistance to fungus, salt spray, sand, dust, humidity, etc. Materials and workmanship are in accordance with ANE-19. It has a life expectancy of 1,000 hours. Radio frequency noise, both radiated and conducted, is within the limits prescribed by AN-I-225.



Static Phase Adapters consisting of the phase splitting network proper, without electronic controls or time delay, may be furnished for use on certain fixed load applications. These devices give balanced three phase voltages over limited ranges of frequency, input voltage and load. Either larger or smaller units may be furnished. Their use is limited by the fact that where large amounts of three phase power is required, it is often desirable to use a separate three phase source, and where smaller amounts are required, relatively small savings are found in designing lower power phase adapters. Phase adapters of either static or electronic type may be supplied to furnish two phase rather than three phase current. Specifications are similar to those above.

Varo Mfg. Co., Box 638, Garland, Texas

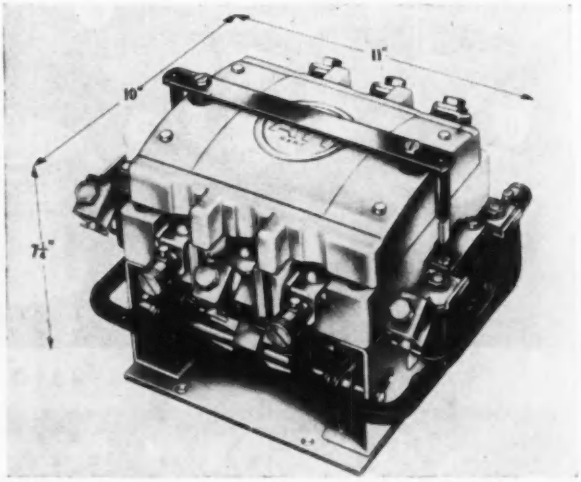
Circle No. 7 on Reader Service Card

Balanced Mechanism Gives Compact Magnetic Starter

This new size 4 magnetic starter has been designed for compactness with a right angle, balanced mechanism to lighten the dead weight load. A knee action bell crank multiplies the leverage and transfers it from a verticle to a horizontal plane. Control power consumption is cut.

The moving parts are aligned on four pillar guides to give steady straight line action and positive contact. Heat resistant silicon chutes enclose each contact. The arc across quenching plates and the contacts is shaped to form a magnetic blow-out field to force the arc into the baffle plates.

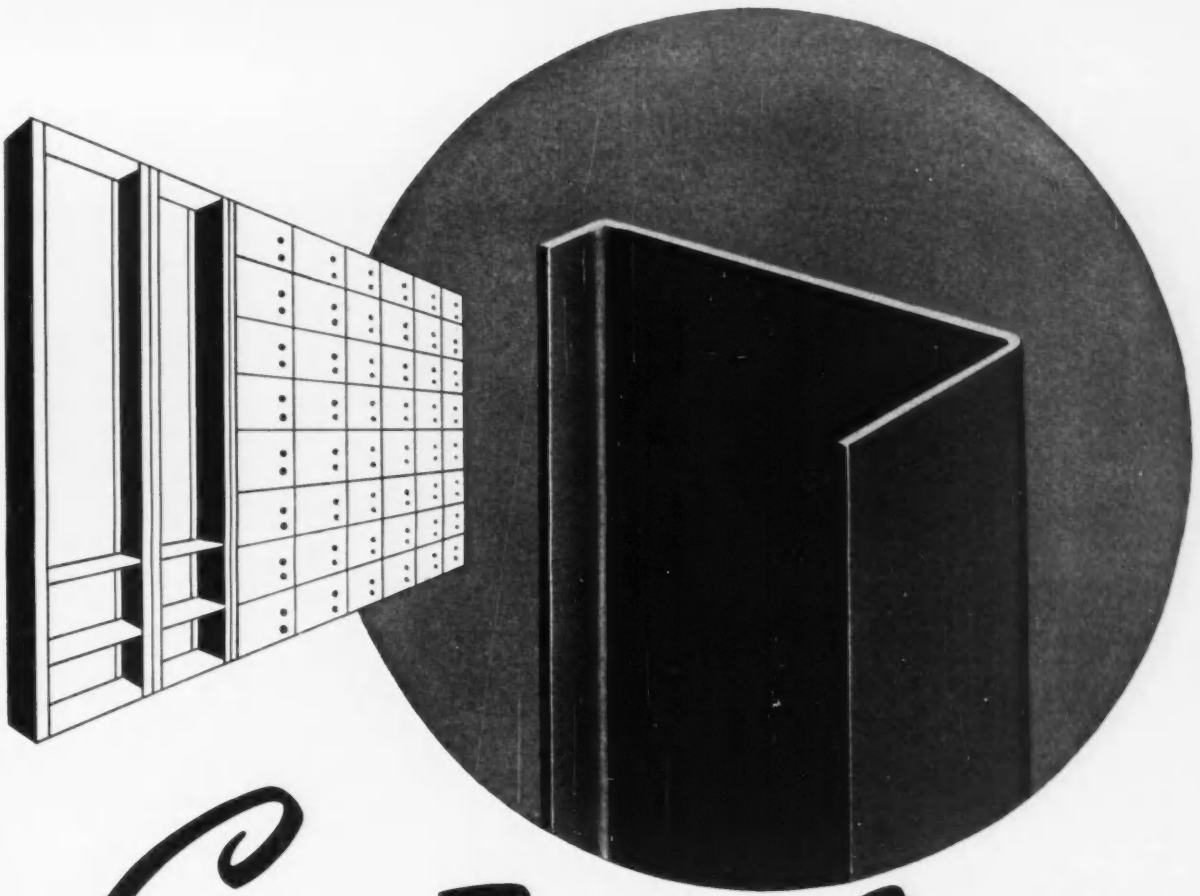
Wiring is straight through and terminals and contacts are readily accessible. Calibrated thermal overload relays are supplied with one-piece interchangeable heaters. Protective hood and base are molded from thermosetting alkyd. The solenoid power consumption has been kept low to give what is claimed as the minimum commercial heat size. A range of rated heaters is supplied. The complete unit measures 11 by 7¼ by 10 in. high.



The Arrow-Hart & Hegeman Electric Co., 103 Hawthorn St., Hartford 6, Conn.

Circle No. 8 on Reader Service Card

CONTINUED ON PAGE 162



COLD-FORMED CHANNEL

USED BY MAKER OF TELEPHONE EQUIPMENT

This cold-formed channel is used as an upright support for telephone central office equipment. It has a 5-in. web and uneven legs, one being 7/8 in., the other 2 7/16 in. long. We make it on brakes, using 1/8 in. commercial-quality steel, and furnish it pickled and oiled in lengths of approximately 11 1/2 ft.

Cold-formed channels are representative of the hundreds of ways in which Bethlehem Cold-Formed Shapes are chalking up economies for manufacturers. And hardly a day goes by but that someone, somewhere, thinks up a new use for these versatile, easy-to-work shapes.

Bethlehem Cold-Formed Shapes are made from strip, sheets or plates. They are uniform in thickness, and have a high strength-weight ratio. Their fine surface finish is relatively free from rust and scale. They are easy to fabricate and weld. They are made in all gages from 7 to 24, inclusive.

In looking about your plant, you'll probably find at least one, and maybe several places where Bethlehem Cold-Formed Shapes can be used advantageously. If you would like to discuss the possibilities, we're at your service at any time.

BETHLEHEM STEEL

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation
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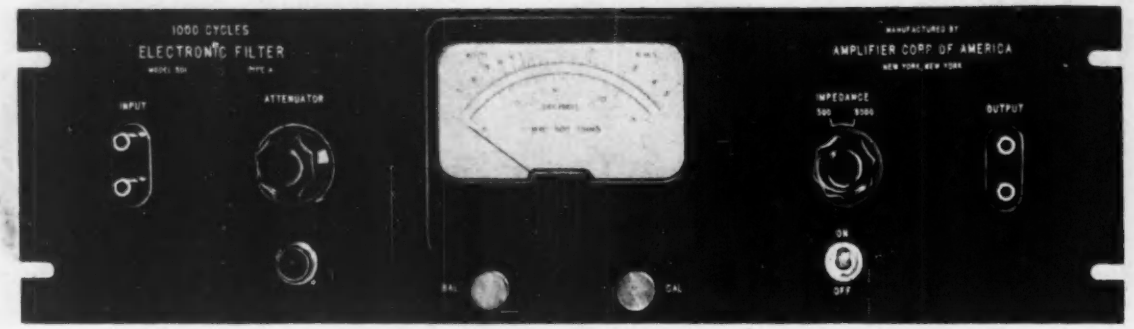
Filters and Amplifiers Give Control Accuracy



A series of electronic filters and tuned amplifiers designed for audio and specialized electronic fields, to improve measurement accuracy and control sensitivity of networks involving single frequency circuits, is now in production. Six standard instruments are available in each series, providing pass frequencies and tuned frequencies of 400, 500, 1,000, 2,000, 3,000 and 10,000 cycles. Multi-tuned amplifiers and multi-filters utilizing switching networks for selecting predetermined frequencies are available.

The principle of the circuit which is the basis of a series of these sharply tuned electronic filters and single frequency amplifiers is a modification of the Wein bridge (which uses only resistance and capacitance) in combination with a compound feedback circuit to create a selective frequency sensitive network. A dual looped network is employed, which consists of a combination of positive and negative feedback, arranged so that positive feedback is predominant at the pass frequency while negative feedback prevails throughout the remainder of the audio spectrum. Transmission gains in the order of 30 db are obtained.

With this equipment, a control or measurement circuit which depends upon single frequency bridge balance is claimed to be made 10,000 times more accurate and sensitive, with the use of an electronic filter between signal source and bridge and a tuned amplifier between the bridge output and null detector.

An optional feature available with any electronic filters or tuned amplifier is the built-in vacuum tube logarithmic voltmeter. The noise level of this series of amplifiers is specified as less than 1 microvolt, referred to their input terminals.

Other unusual claims made for these instruments are: virtually constant input and output impedance at all audio frequencies; attenuation rate, at either side of pass frequency, 40 db per octave; elimination of iron cored inductors; compensated frequency sensitive elements; pass frequency adjustable ± 2.5 per cent; response characteristics insensitive to voltage overload, source or sink impedances, capacitances or inductances; electronic filters provide minimum of 30 db selective insertion gain; pass characteristics remain constant with power level and temperature; high "Q" effects obtained without inductors; no external fields.

The tuned amplifiers include, in addition to the frequency selective network and output stage, a low-noise level input bridging stage which may be coupled to any impedance source under 500,000 ohms. Where balanced input or output circuits are required, auxiliary input and output transformers may be added. With the inclusion of the optional output indicating meter, the electronic filters or the tuned amplifiers are designed as complete indicating instruments.

The phase-shifted characteristics of the partially rejected adjacent frequencies makes these units suitable for a variety of sensitive phase discriminatory control circuits. Their rejection characteristics also make them suitable for use as wave-shaping networks to produce sinusoid wave trains or pulses from multivibrators or pulsing networks.

Instrument Div., Amplifier Corp. of America, 398-13 Broadway, New York 13, N. Y.

Circle No. 9 on Reader Service Card

Regulator Holds Constant D-C Generator Voltage

A new carbon pile voltage regulator is available. Approved for use of military aircraft, the regulator will maintain a constant voltage output on a 30 v, 100 to 400 amp d-c generator over its range of speed and load. It weighs 2.75 lb.

Rated at 90 w, the regulator has a carbon stack resistance range of 125 to 35 ohms. The unit will carry an overload current of 15 amp through the carbon stack for one hour. When two or more generators and regulators are operated in parallel, equal load division is maintained.

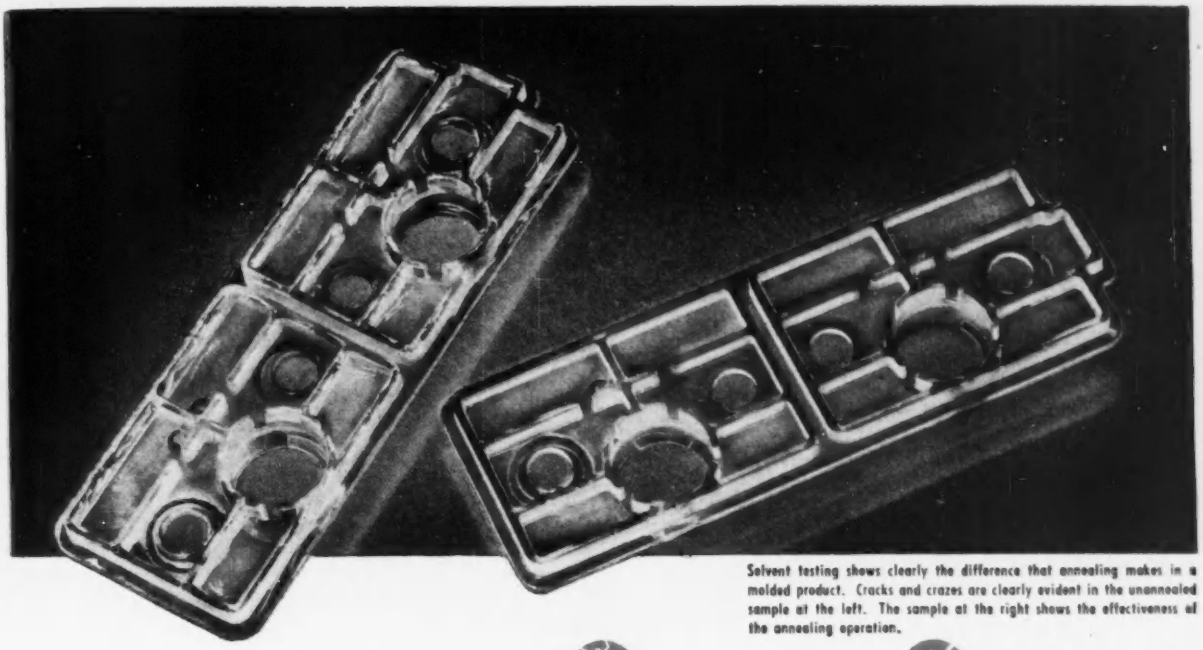
Regulator armature friction is reduced by the use of a single leaf cantilever spring which bears on a polished surface. A molded ceramic insulator holds the carbon contact and reduces heat transfer from stack to spring.

Carbon disks are thick enough to permit lapping smooth and parallel to within 0.0004 in.

Westinghouse Electric Corp., P. O. 2099, Pittsburgh 30, Pa.

Circle No. 10 on Reader Service Card

CONTINUED ON PAGE 164



Solvent testing shows clearly the difference that annealing makes in a molded product. Cracks and crazes are clearly evident in the unannealed sample at the left. The sample at the right shows the effectiveness of the annealing operation.

Now you can control Crazing and Cracking by annealing your Polystyrene

Get the full story of this process from Koppers Technical Department

INTERNAL stresses and strains that result in crazing and cracking of plastic products can be a major cause of excessive rejects and failures in service. Molders are discovering they can reduce this waste of material, time and labor and produce a better, more lasting job by *annealing* their finished products.

Koppers Technical Service Department has done extensive research on annealing of Koppers Polystyrene and now makes the results of this research available to you in a Technical Service Report. It's another example of Koppers efforts to help manufacturers and molders achieve reduction in costs through use of versatile Polystyrene.

All three types of Koppers Polystyrene are well adapted to various annealing processes. Their heat distortion temperature permits you to employ the proper heat treatment safely. In addition, you can take advantage of the low molding costs, low material costs and improved product appearance by using Koppers Perfected Polystyrene.

Why not get the complete story on annealing? Send for your copy of Technical Service Report No. 2, "Annealing of Polystyrene." A copy of "Koppers 1950 Polystyrenes" is also available for your use. Just mail the coupon.

KOPPERS POLYSTYRENE
gives you all these advantages

- **Low cost**
- **Light weight—more pieces per pound**
- **Excellent dimensional stability**
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- **Choice of heat distortion temperature ranges**
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Koppers Company, Inc.
Chemical Division, Dept. PE-70
Pittsburgh 19, Pa.

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☐ "Annealing of Polystyrene"
☐ "Koppers 1950 Polystyrenes"

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KOPPERS COMPANY, INC.
Chemical Division Pittsburgh 19, Pa.
Regional Offices: New York, Boston, Philadelphia, Chicago, Detroit and Los Angeles

KOPPERS

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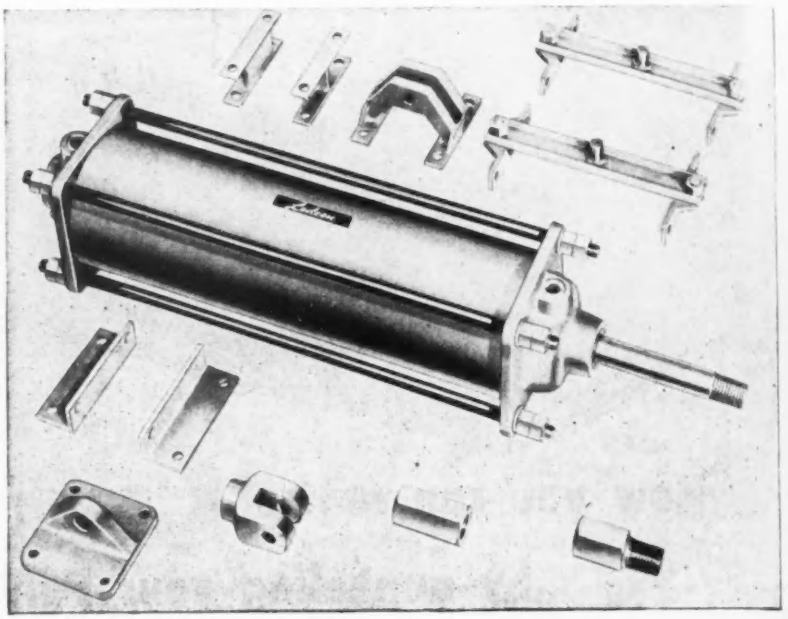
Cylinder Line Operates to 200 Psi

A new line of cylinders, limited to 200 psi, has been offered by this manufacturer to supplement an existing line of heavier equipment. Diameters from 1½ to 8 in. and strokes up to 36 in. are available. Cylinders tubes are yellow brass and pistons are aluminum with simple synthetic cups. Hydraulic cylinders are equipped with heavy neoprene cups, while steam and high temperature cylinders are fitted with special cups. Cast iron cylinder heads are used.

Automatic cushion is provided on all units, while adjustable cushion may be had on special order. Chevron packing is standard on all cylinders. Attachments are available for heads and rods as illustrated. Special attachments can be had on order. Stroke lengths are standardized at 6, 12, 18, 34 and 36 in., with other lengths provided on order.

Ledeen Mfg. Co., 1600 S. San Pedro St., Los Angeles 15, Calif.



Circle No. 11 on Reader Service Card

In-Line Pipe Joint Takes Up Expansion

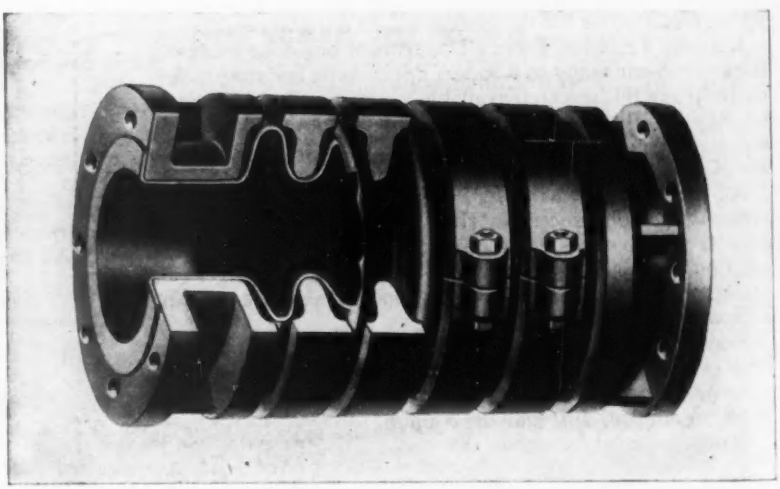
Expansion and contraction caused by temperature changes in pipes are taken up by these packless, in-line, corrugated expansion joints. Two types are available, one equipped with bolted control rings (illustrated), and another, without rings, for use with lower pressures.

Joints of copper, stainless steel, or other alloys, are available in size ranges from 3 to 24 in. ID. Units are fabricated with single or multiple corrugations and may be had with flanged or welding ends. Stainless steel inner liners, tie rods and special flanges and welded combinations are available to meet requirements.

Axial pipeline traverse of 7½ in. can be taken-up with a single Controlled-Flexing joint—traverse of 15 in. in a single pipe run can be had with a "dual" Controlled-Flexing joint. A "dual" joint consists of two joints joined by an inter-connecting nipple. Lateral motion of $\frac{1}{16}$ in. per corrugation, or a maximum offset of 1 in. can also be handled. Joints operate under pressures to 300 psi and temperatures to 1,600 Fahrenheit.

Used instead of pipe bends, the new joints eliminate the cost of extra pipe needed for the bends, insulation costs of this extra pipe, and heat losses due to the extra surface.

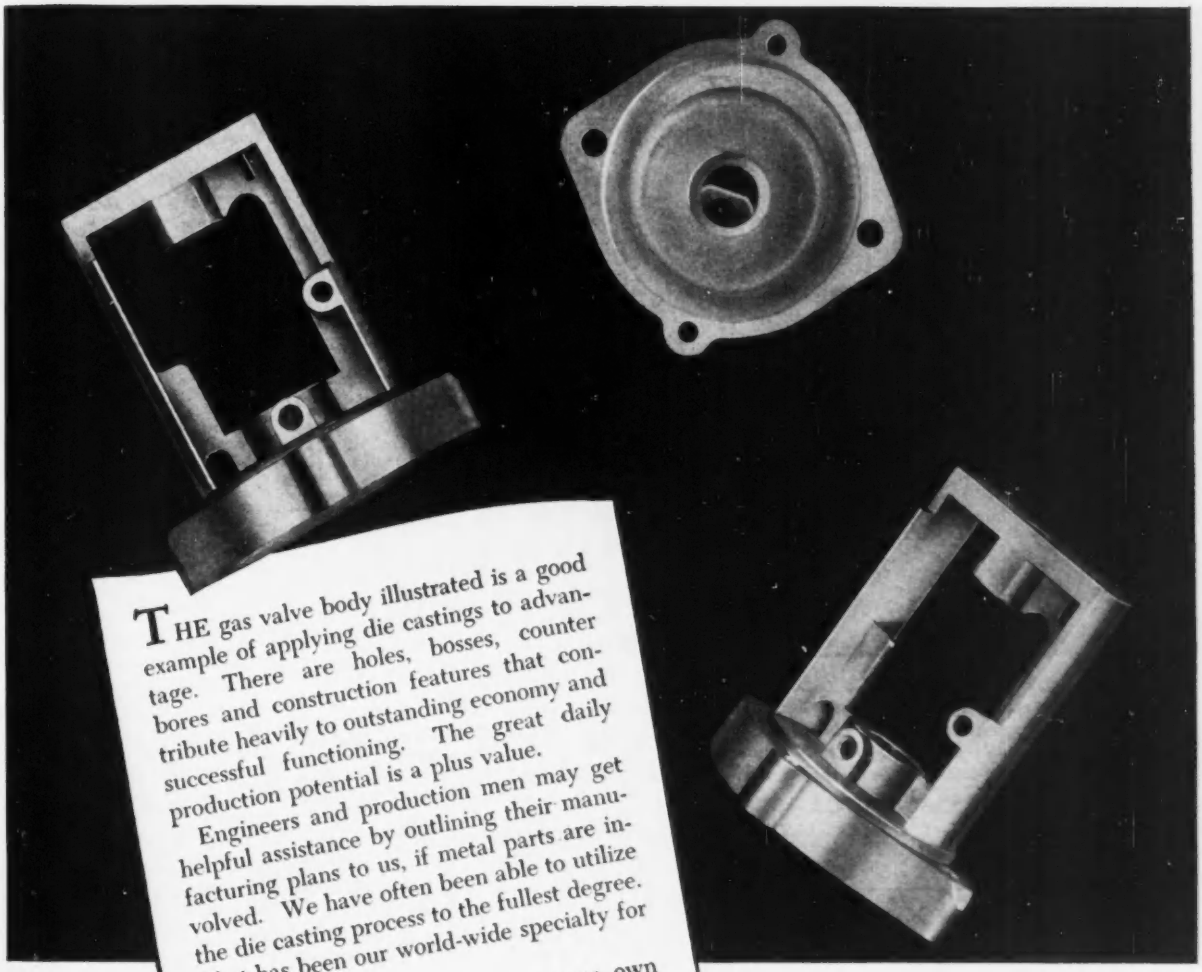
Chicago Metal Hose Corp., Expansion Joint Div., 1306 S. Third Ave., Maywood, Ill.



Circle No. 12 on Reader Service Card

CONTINUED ON PAGE 166

PRODUCTION PLANNING IS OFTEN SIMPLIFIED WITH MADISON-KIPP ZINC AND ALUMINUM DIE CASTINGS



THE gas valve body illustrated is a good example of applying die castings to advantage. There are holes, bosses, counter bores and construction features that contribute heavily to outstanding economy and successful functioning. The great daily production potential is a plus value.

Engineers and production men may get helpful assistance by outlining their manufacturing plans to us, if metal parts are involved. We have often been able to utilize the die casting process to the fullest degree. That has been our world-wide specialty for many years.

It may pay you to canvass your own situation on parts and to write us at our home office in Madison, Wisconsin.

MADISON-KIPP CORPORATION

206 WAUBESA STREET, MADISON 10, WIS., U.S.A.

ANCIENS ATELIERS GASQUY, 31 Rue du Marais, Brussels, Belgium, sole agents for Belgium, Holland, France, and Switzerland.

WM. COULTHARD & CO. Ltd., Carlisle, England, sole agents for England, most European countries, India, Australia, and New Zealand.

- *Skilled in* DIE CASTING *Mechanics*
- *Experienced in* LUBRICATION *Engineering*
- *Originators of Really High Speed* AIR TOOLS

UNIVERSITY OF MICHIGAN LIBRARIES

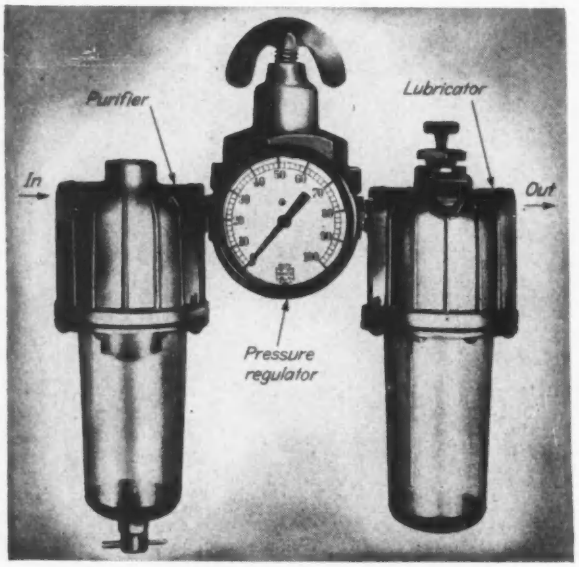
Compressed Air Unit Cleans, Controls and Lubricates

Moisture and dirt are removed from air and gas lines and a fine mist of lubricating oil is added to the pressure controlled outflow of a new valve design. The oil is in the form of a fine, suspended mist before it is taken into the main air stream, and the elimination of large drops, which accumulate in pipes and spray from operating machinery, is claimed.

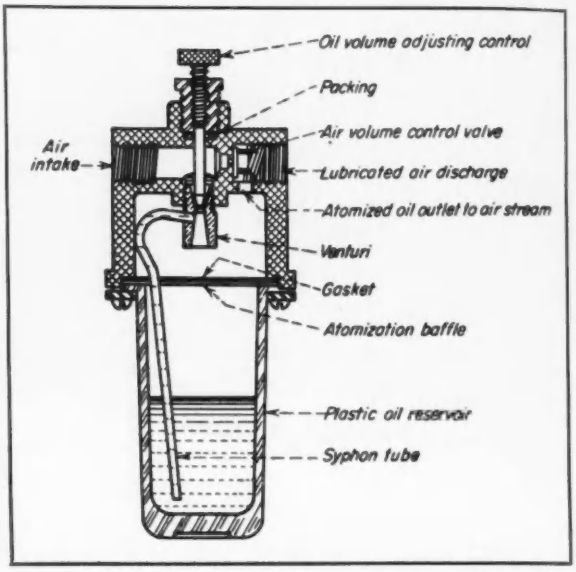
Purification is accomplished in the first component. Foreign substances are drained into a plastic bowl which is transparent to allow visual checking. Drainage is provided through a petcock. The standard unit can take 100 psi, while 250 psi can be handled with metal bowls.

The amount of oil added to the air supply is regulated by an adjusting screw. Oil volume is automatically adjusted to air pressure variations. The plastic lubricator reservoir holds ½ pint, and the entire unit weighs 2 lbs. Low oil consumption, through efficient vaporization, is claimed.

Airlube, Inc., 3422 W. North Ave., Chicago 47, Ill.



THE NEW CONTROL ASSEMBLY consists of three units. At the left is the purifying mechanism, designed to trap moisture and solids by impingment and scrubbing action on a series of baffles. In the center is the air pressure regulator with gage. The lubricator is the last unit the air passes through. Here it is charged with atomized oil particles.



THE CLEAN, DRY AIR passes from the regulator into this lubricator. Most of the air goes through the air volume control valve to discharge. A metered air volume, however, is directed through the venture by the oil volume control valve. Oil is sucked into the stream and broken up by impingment on the atomization baffle. This air then leaks into the discharge.

Circle No. 13 on Reader Service Card

Standard Boosters Can Replace Pumps

This line of fluid pressure boosters is offered in standard models. The manufacturer utilizes interchangeable parts from standard production air and hydraulic cylinders to produce pressure boosters of any size. New seals allow the units to hold pressures without motion or heat generation. They can be substituted for pumps on simple circuits requiring a small to medium volume of high pressure oil per cycle.

Air operated, single acting boosters are offered with spring return for operation on single pressure circuits. Input pressures are air and output is in hydraulic pressure. The single acting cylinders are offered in bores from 3¼ to 8 in. Strokes in excess of 8 to 12 in. are not recommended. Newly developed seals make low speeds possible.

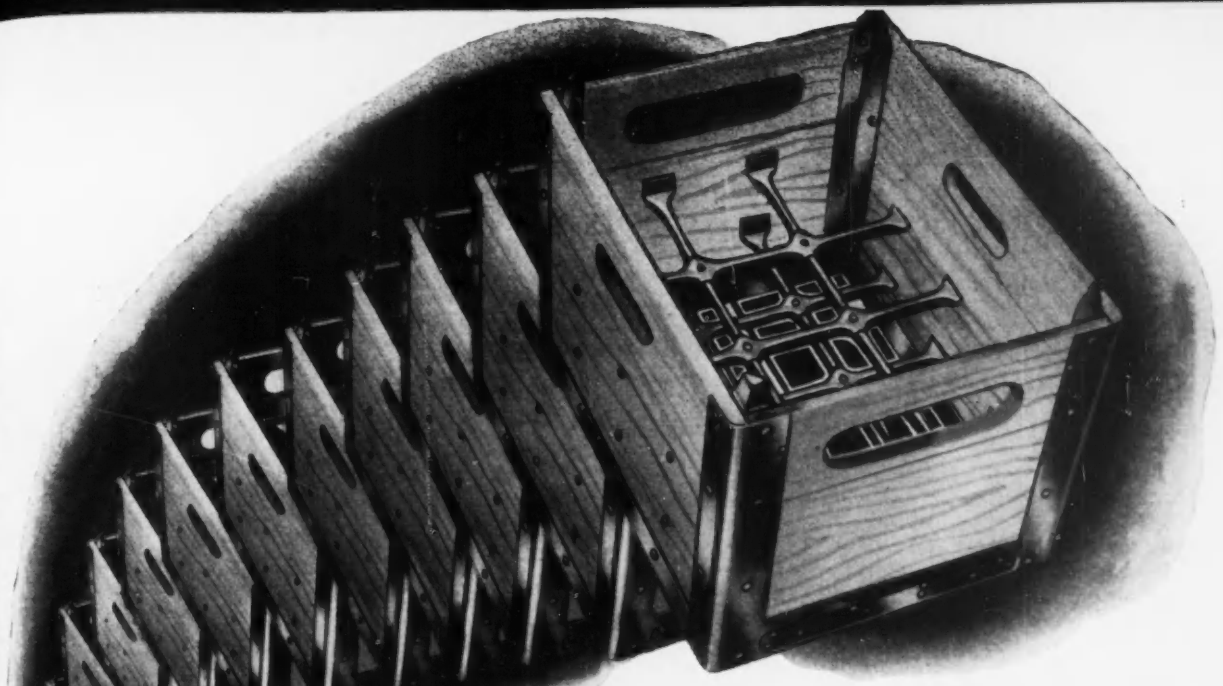
Another line is either air or oil operated, in single or double acting units. Output on these must be hydraulic. Dual pressure systems may be used where a long, low pressure approach stroke followed by a short, high pressure working stroke is desired.

In each of these lines, outputs from 300 to 3,400 psi hydraulic pressure are available using 100 psi input. Higher output pressures up to 10,000 psi result from higher input pressures. Metallic rod seals can be used with pressures above 3,000 psi. No castings are used and heads, caps and mountings are machined from solid steel bar stock. Air driven boosters use honed brass tubing. Operating speeds range from 30 to 450 strokes per minute.

Millter Motor Co., 4027 N. Kedzie Ave., Chicago 18, Ill.

Circle No. 14 on Reader Service Card

CONTINUED ON PAGE 168

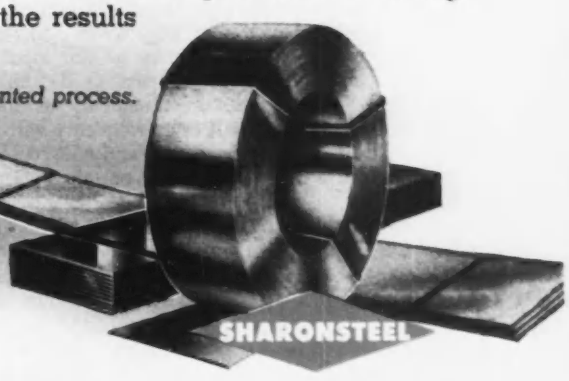


A *Case* HISTORY
ALL STEEL USERS SHOULD KNOW ABOUT

Maintenance of containers has long been an expensive "headache" to those who market their products in bottles. Part replacement and general upkeep usually exceed the original cost many times over. That's why recently one leading manufacturer of cases —after considerable experimentation with materials—switched to Galvanite*.

Galvanite is prime steel with a tight zinc coating. It has superior strength and toughness—yet is ductile and easy-working. The generous zinc coating, applied by special process, makes Galvanite rust and corrosion resistant even in salt air areas. And this tight coating stays put—it won't peel or flake during the severest fabrication — dies stay clean and scrap loss is held to a minimum. Next time you want a strong, easy-working, rust-resistant steel try Galvanite — the results will impress you.

* *Produced solely by the Sharon Steel Corporation under patented process.*



Whenever Weather is a Problem
GALVANITE *is the Answer*

SHARON STEEL CORPORATION *Sharon, Pennsylvania*

PRODUCTS OF SHARON STEEL CORPORATION AND SUBSIDIARIES: THE NILES ROLLING MILL COMPANY, NILES, OHIO; DETROIT TUBE AND STEEL DIVISION, DETROIT, MICHIGAN; BRAINARD STEEL COMPANY, WARREN, OHIO; SHARONSTEEL PRODUCTS COMPANY, DETROIT, MICHIGAN, AND FARRELL, PENNA.; CARPENTERTOWN COAL & COKE CO., MT. PLEASANT, PENNA.; FAIRMONT COKE WORKS, FAIRMONT, W. VA.; MORGANTOWN COKE WORKS, MORGANTOWN, W. VA.; JOANNE COAL COMPANY, RACHEL, W. VA. Hot and Cold Rolled Stainless Strip Steel—Alloy Strip Steel—High Carbon Strip Steel—Galvanite Special Coated Products—Cooperage Hoop—Electrical Steel Sheets—Hot Rolled Annealed and Deoxidized Sheets—Galvanized Sheets—Enameling Grade Steel—Welded Tubing—Galvanized and Fabricated Steel Strip—Steel Strapping, Tools and Accessories.

DISTRICT SALES OFFICES: Chicago, Ill., Cincinnati, O., Cleveland, O., Dayton, O., Detroit, Mich., Indianapolis, Ind., Milwaukee, Wis., New York, N. Y., Philadelphia, Penna., Rochester, N. Y., Los Angeles, Calif., San Francisco, Calif., St. Louis, Mo., Montreal, Que., Toronto, Ont.

UNIVERSITY OF MICHIGAN LIBRARIES

Magnetic Starter Adopts to Circuit Conditions

Start-stop control and thermal overload protection are provided for polyphase and single-phase squirrel-cage motors by this new magnetic starter. General purpose and weatherproof enclosures for sizes to 5 hp, 220 v a-c, or 7½ hp, 440-550 v a-c are offered. Built in push buttons, a selector switch for changeover from automatic to hand operation, or a built-in pilot control for remote operation, can be provided.

Dual voltage coils are used with single and polyphase starters to allow voltage changes without substituting coils. Coils can be matched to dual voltage motors, and are available for 60, 50 and 25 cycles in standard voltages. Two interlock switches can be added for extra circuits. One normally open and one normally closed switch are included in each interlock.

The terminal board is molded with arc barriers to prevent flash-over. The cross arm is pushed up by the magnet to engage the movable silver contacts it carries with the set in the terminal board. Contact pressure is maintained by stainless steel springs mounted behind the silver contacts in the movable cross arm. A silicon steel magnet is used and the movable plunger slides in a one-piece phosphor-bronze guide. Magnet hum is minimized by rubber mounting.

Solder-pot overload relays are easily accessible. A button operates the reset lever through the cover. When the button is pressed the overload relays are reset and the main contacts are held open so that the motor will not start if the solder-pot alloy is not solidified. This feature also provides an emergency stop.

Furnas Electric Co., 105 McKee St., Batavia, Ill.

Circle No. 15 on Reader Service Card

D-C Amplifier Approaches Natural Electronic Limit

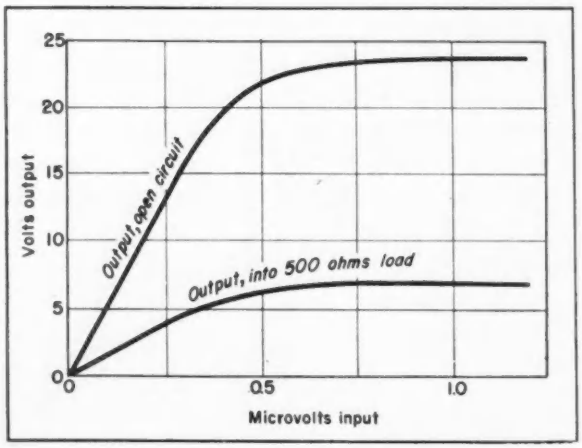
This amplifier is of the General Motor's breaker type and is capable of approaching the natural limits of amplification imposed by the random motion of electrons. It operates from 110 v, 60 cycle and consumes 20 watts. It can be supplied for 50 v operation. The unit measures 22 x 15 x 10½ in. and weighs 60 pounds.

The amplifier consists of a motor driven breaker to convert the d-c signals to a-c for amplification. After amplification, the a-c is converted back to d-c by a breaker operating synchronously with the input breaker. The use of this synchronous output breaker has several advantages. First, the amplifier will produce either negative or positive output voltages depending on the polarity of the input signal. Second, the output breaker will pass as d-c only those signals which are of the same frequency as the input breaker. Voltages other than breaker frequency will produce only an a-c component in the output and will consequently be discriminated against by a meter or other intergrating device.

The new amplifier employs an 8 cycle breaker. This low breaker speed plus careful design of the amplifier circuit gives a discrimination against the effects of 60 cycle and higher frequency pick-up which is over 1,000. The effectiveness of this discrimination is demonstrated by the fact that a-c is employed for the pre-amplifier heater with resulting circuit simplification and increased reliability.

The drift of the amplifier is less than 0.005 microvolts in 8 hours. With a stable line the amplifier will vary less than 0.3 percent over the same period. Gain will vary less than 0.5 percent for voltage variation of 10 percent.

The instrument is provided with a course gain of 20 positions, 4 DB per position. A fine gain control permits interpolation. For calibration, 7 signals are provided.

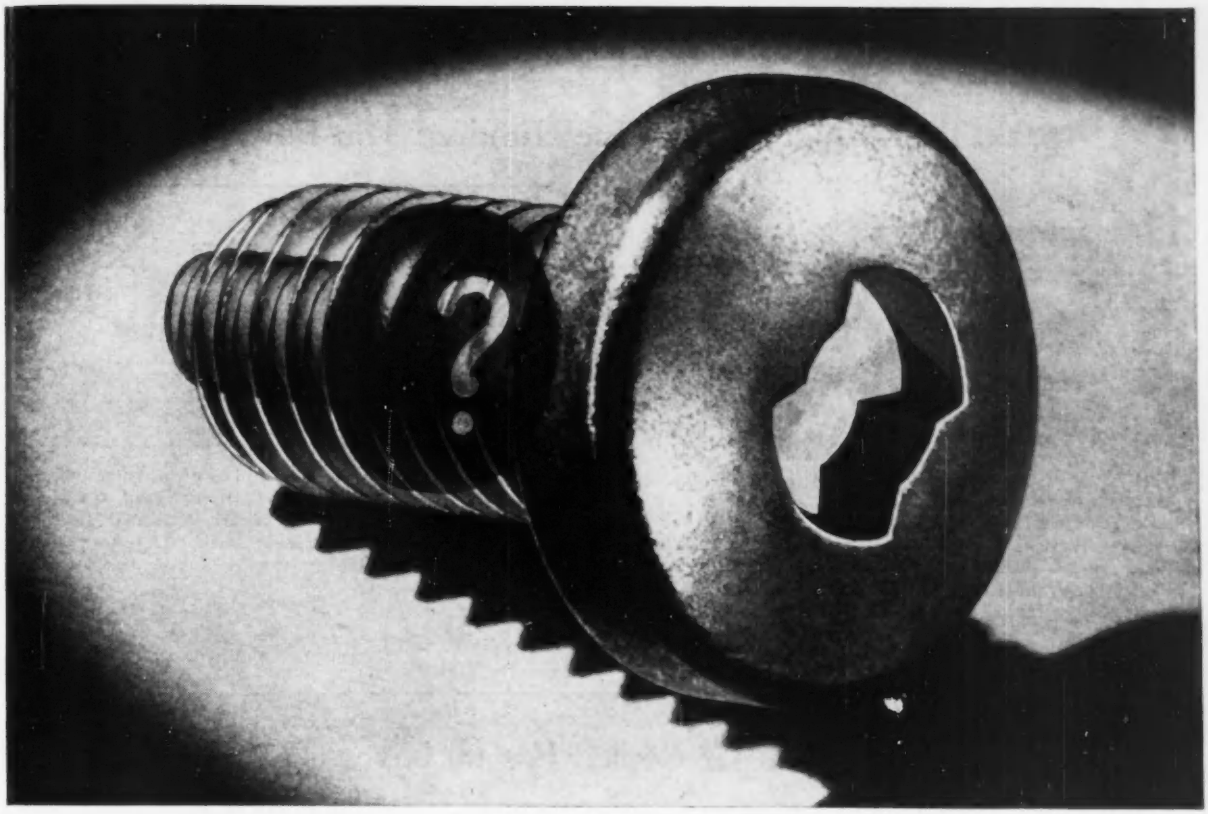


OUTPUT CHARACTERISTICS with 20 ohm resistance in external circuit and maximum gain. The curvature in the upper part is due to overloading the output tube.

Liston-Folb, P. O. Box 1334, Stamford, Conn.

Circle No. 16 on Reader Service Card

CONTINUED ON PAGE 170



Over What Other Screws Does

CLUTCH HEAD STEP-UP PRODUCTION *50%?*

Over All Other Type Screws...

RECESSED HEADS AS WELL AS SLOTTEDS

TYPE "A" ASSEMBLY BIT

COMMON SCREWDRIVER

CLUTCH HEAD'S modern design meets today's competitive selling problem of how to "Produce More For Less" . . . by effecting time and cost-savings that quicken production steps all the way down the assembly line. On the basis of experience resulting from changeover from other types of recessed head screws, here is how these users score CLUTCH HEAD supremacy:

High visibility of the clutch recess inspires operator confidence for unhesitating faster driving, while dead-center entry with the Center Pivot Column prevents driver canting. Straight driving is automatic . . . hence no burred or chewed-up heads.

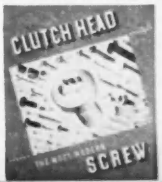
Absence of "ride-out," due to CLUTCH HEAD'S non-tapered driving engagement, checks out hazard of driver skidding. Freedom from end pressure makes driving effortless, safer and smoother for a stepped-up tempo.

The Lock-On to check out fumble spots . . . screw and bit locking as a unit to permit one-handed reaching and driving from any angle.

The unequalled durability of the Type "A" Bit with a record of driving 214,000 screws non-stop . . . plus the economy of its repeatable reconditioning in a simple 60-second operation.

The importance of CLUTCH HEAD'S basic design for common screwdriver operation . . . to simplify adjustments and cure field service "headaches."

These exclusive CLUTCH HEAD *advantages are illustrated and detailed in this new Brochure.*



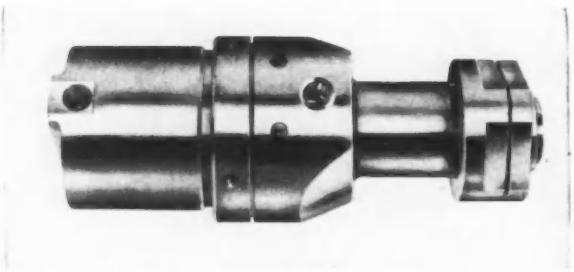
Your copy will come to you by mail on request with mention of the types and sizes of screws in which you are interested.

UNITED SCREW AND BOLT CORPORATION

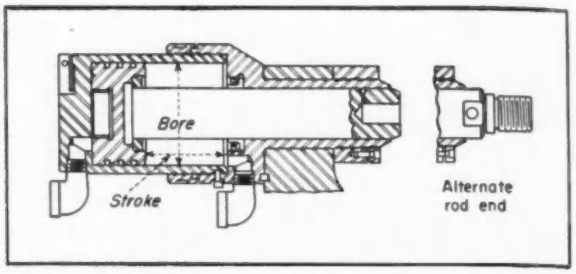
CLEVELAND 2 CHICAGO 8 NEW YORK 7

UNIVERSITY OF MICHIGAN LIBRARIES

5,000 Psi Cylinder Gives One Hundred Ton Power Stroke



NEW CYLINDERS are intended for push applications with the manufacturer's special pump, supplying 1,000 psi on approach and return and automatically jumping to 5,000 psi for power stroke. Bore sizes range from 2 to 7¼ in., and strokes up to 6 in. are available. Output forces on push strokes can reach 100 tons. The cylinder body is heat treated alloy steel with ground bore. Nine standard sizes are made for yoke or frame mounting.



PISTON IS THE FLOATING TYPE with ground step-seal rings. The piston rod is alloy steel, case hardened, and ground. The rod moves through an alloy steel, heat treated, gland bearing fitted with self-adjusting packing. The high pressure end of the cylinder is of one-piece construction and requires no sealing.

Hannifin Corp., 1126 S. Kilbourn Ave., Chicago 24, Ill.

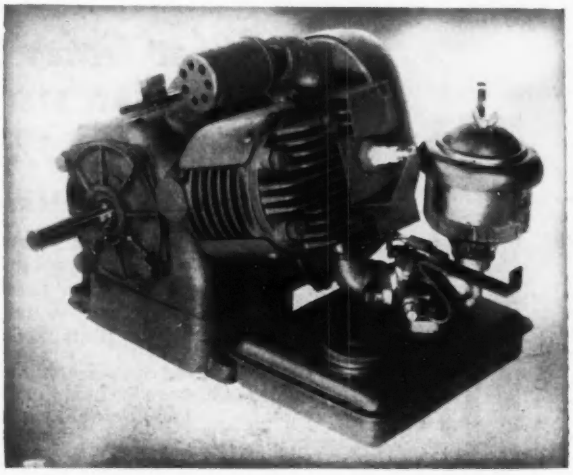
Circle No. 17 on Reader Service Card

Low Profile Air Cooled Engine Gives 1½ Hp

Two air-cooled industrial engines are offered in low-profile models. One is rated at ¾ to 1 hp, while its companion model has a 1½ hp rating. Overall height is less than 9½ in. in both.

The new units are single cylinder, four cycle, L-head engines, with 2⅛ in. bore and 2 in. stroke, a displacement of 7.1 cu in., and compression ratio of 5.2 to 1. The crankshaft is supported on ball bearings at the power take-off end and by a replaceable bronze thrust bearing at the cranking end. The heat- and corrosion- resistant silchrome steel exhaust valve is seated in an alloy steel insert. Standard equipment includes an oil-bath air cleaner, dust and moisture-proof flywheel-type magneto, blower housing, muffler, 1 qt fuel tank and an air vane governor. The engines are cranked by rope and handle.

Special equipment also available includes recoil or kick starter, remote throttle control, ignition lock and reduction gearing, supplied in any of four mountings.



Continental Motors Corp., 626 Ford Bldg., Detroit 26, Mich.

Circle No. 18 on Reader Service Card

More Strength Built Into Permanent Magnets

Permanent magnets with a guaranteed energy product of at least 5¼ million BHmax are now being manufactured. A new production technique is applied to the standard alloy to give 16 percent greater strength than was possible with former magnets.

A dispersion hardened alloy of aluminum, nickel, cobalt, copper and iron is cast to the required shape. Finished surfaces are ground, and required holes are cored. The magnets are anisotropic —that is, have much better magnetic properties in a preferred direction. This effect is obtained by cooling the magnets from the normalizing temperature at a controlled rate in a magnetic field of the same configuration as that desired in the finished product. The high temperatures and field strengths required impose some limitations on the size and shape of magnets. Tensile strength is 5,400 lb/in.^{2}, and coefficient of thermal expansion per deg C is 11.3 x 10^{-6}.

The Indiana Steel Prod. Co., Valparaiso, Ind.

Circle No. 19 on Reader Service Card

CONTINUED ON PAGE 172

ELECTRUNITE

ELECTRICALLY-WELDED TUBING

Looking for a way to cut deadweight from your new or existing products . . . a way to make them easier to carry, easier to move, or easier to lift? Then consider carefully the use of Republic ELECTRUNITE Tubing from a structural standpoint.

Modern ELECTRUNITE Tubing possesses an extremely high strength-to-weight ratio. There are practically no limits to its ability to take fabrication. It can be painted with ease and plated with a minimum of preparation. In many cases, its cost is less than that of other materials.

ELECTRUNITE Tubing is available in a full range of sizes, gages and analyses—both carbon and stainless steel. Write for complete information *today*.

REPUBLIC STEEL CORPORATION
STEEL AND TUBES DIVISION • CLEVELAND 8, OHIO
Export Department: Chrysler Building, New York 17, New York

Republic
REPUBLIC STEEL
ELECTRUNITE TUBING

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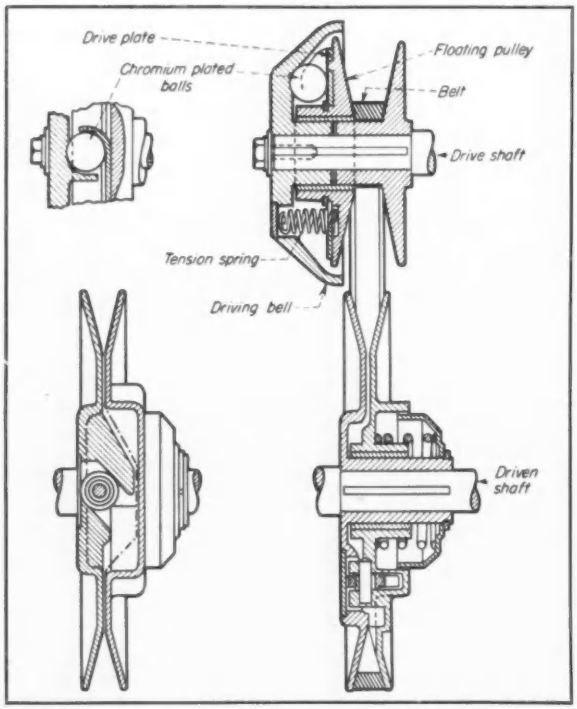
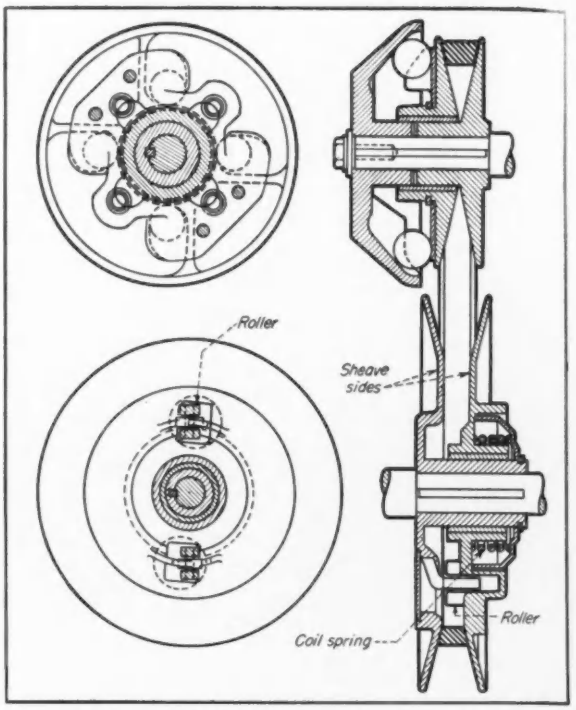


IN THE IDLE POSITION four springs hold the drive floating pulley out of contact with the belt, which rests lightly on the chrome plated hub. Between the driving bell and the drive plate are 4 chromium plated balls, acting as centrifugal weights and floating keys to carry the driving load. The tension springs hold the balls in control with lips from the driving plate and bell. The plate is attached by lugs to the floating pulley. As the speed of rotation increases the balls tend to move out and increase the pitch diameter.



IN HIGH SPEED POSITION we see the drive pulley at maximum pitch diameter. The driven member consists of two sheave sides, one sliding on an "oilite" bushing on the chromium plated hub of the other. Belt tension is normally maintained by the coil spring. Under heavy torque, the belt pressure is increased by cam action of the rollers, which operate on inclined ramps, with a rotating motion imparted by the creep between the two pulleys. As the torque is decreased, the cam pressure is relieved and the transmission shifts into a higher range.

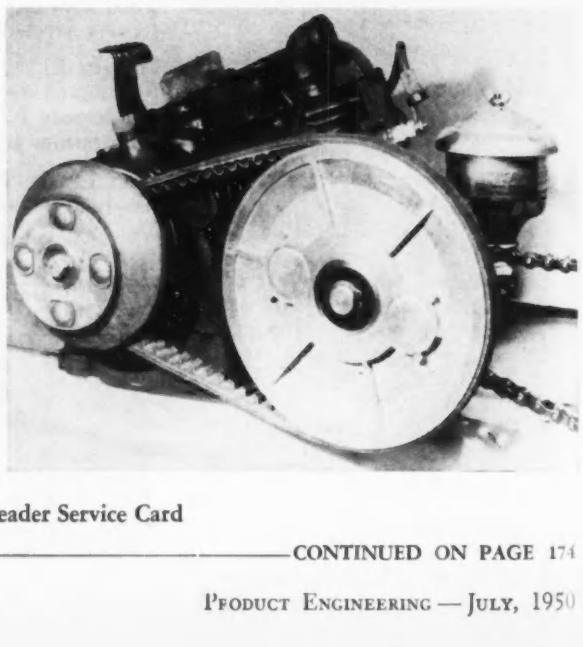
Automatic Transmission Shifts to Fit Speed and Load

Characteristics similar to those of a true hydraulic torque converter mark this variable speed V-belt transmission. On applications from 1 to 5 hp, infinitely varying ratios from 4:1 to 1.6:1 are available. Automatic clutch action and speed-torque responsive shifting are combined in one unit. The best drive ratio is selected to suit the speed and load. The V-belt is automatically gripped tighter under heavy torque loads.

The new installation is almost as compact as a conventional V-belt drive. Manufacturers field tests in small vehicles have promised long belt life. Engine life is prolonged, since heavy hauls are met at high power ratios while engine speed is kept down when peak torque is not required.

Principal parts are aluminum alloy, with steel inserts for hubs. Steel parts are rust-proofed, and no lubrication is required. Applications include small vehicles, air compressors, pumps, hoists and conveyors.

Diesel Pump & Electric Mfg. Co., Culver City, Calif.



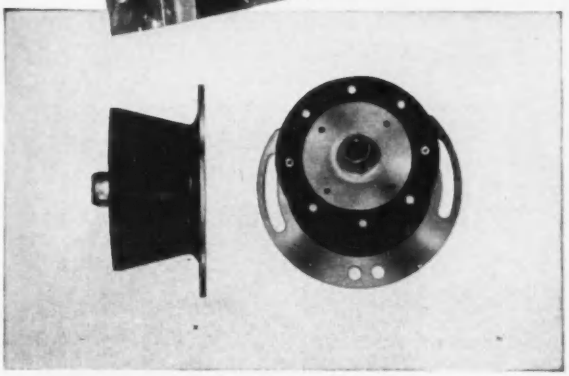
Circle No. 20 on Reader Service Card

CONTINUED ON PAGE 174

NEW RUBBER SPRING PROVIDES UNIQUE BENEFITS

Used on new tractor seat, it eliminates slow-down from rider fatigue . . . increases production

GOOD-BYE TO "ROUGH RIDING." As the tractor rides over rough ground, the seat's rubber torsional springs twist and turn with each jolt, cushioning shock and leveling out the sharp rebound. Result: less fatigue for the farmer . . . greater working efficiency . . . more daily output from the tractor in the same amount of time!



THE PRINCIPLE OF THE THING. These stabilizing springs operate on a torsional principle . . . consist of a thick layer of carefully compounded rubber, sandwiched between metal plates. Springs were especially developed by U. S. Rubber engineers for the manufacturers of this revolutionary new seat.

SMOOTH SEAT FOR EVERYONE. A twist of this tie bolt and the seat spring can be adjusted to provide the utmost comfort for the slimmest farm girl or the huskiest male. Another good example of the results obtained by manufacturers who bring their problems to U. S. Rubber's engineering staff!

Hundreds of different products, from baby carriages to railway cars, can be improved by the use of the new U. S. Rubber Torsional Spring. It may well be that your own product, whether on the market or in the design stage, can obtain with this spring the competitive advantage it requires for real success. The tractor seat above is only one instance of how this versatile development aided a manufacturer. Ask "U. S." engineers to investigate its possibilities for your product. Write

A PRODUCT OF

U.S.RUBBER

SERVING THROUGH SCIENCE

UNITED STATES RUBBER COMPANY

MECHANICAL GOODS DIVISION • ROCKEFELLER CENTER, NEW YORK 20, N. Y.

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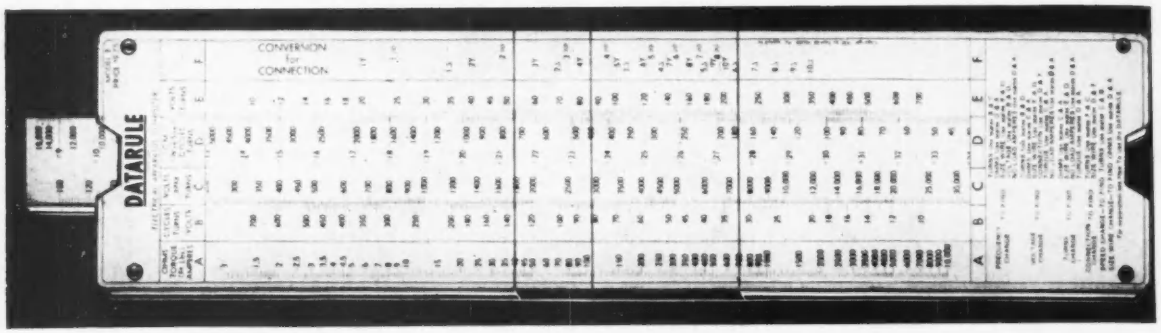
Data Rule Simplifies Electrical Calculations



This plastic data rule is offered for the use of electrical designers to simplify calculations involved in the re-design of apparatus. The new computer is 12 in. long and is provided with a leather carrying case. A 46 page book of instructions, written by the inventer, is also included. The data rule does not eliminate the need for basic knowledge but is offered to assist the engineer in checking design and in performing numerical chores.

In making a frequency change the rule will determine the number of turns needed, the resulting resistance in ohms, the size of wire needed, what voltage can be applied at the new frequency, and the new idle amperage. For a voltage change, the data rule will determine the number of turns required, the resulting resistance in ohms, the size of wire, connection data, change in torque, the new idle amperage, and what size capacitor is necessary. In making a change in turns, the rule will give the amperage, the resistance in ohms, the size of wire needed, the new idle amperage, and the change in torque. The number of turns and the size of wire needed are shown for a connection change. The required number of turns is given for a speed change. For a wire change, the data rule shows the resulting resistance in ohms.

The new computer is designed to minimize formula memorizing and textbook research. Instantaneous answers are given with accuracy claimed to the ampere-turn.

Brownell Distributors, Inc., 308 Canal St., New York 13, N. Y.

Circle No. 21 on Reader Service Card

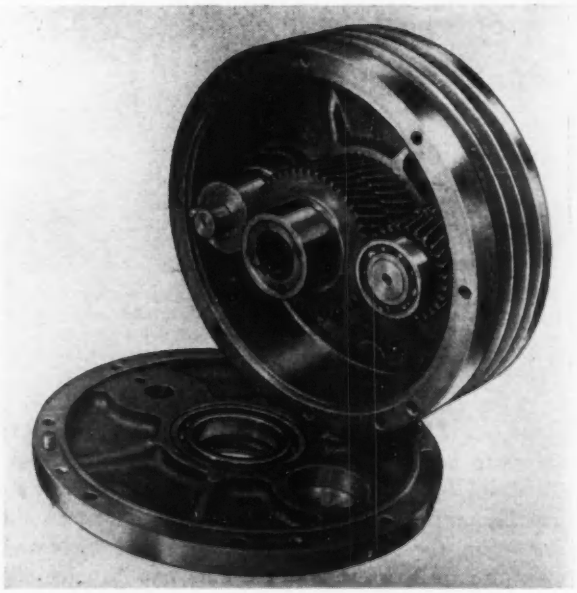
Planetary Gear Reduction Built Into V-Belt Pulley

The gear reduction in this "A" belt pulley consists essentially of a set of planetary gears. Ratios from 4.7:1 to 36.5:1 are standard. This internal gearing and the V-belt reduction between motor and pulley combine to give total reductions up to 150:1. Almost any ratio below the maximum can be obtained by variation of pulley size and gearing.

The entire unit takes up only slightly more space than a conventional pulley. It is held on the shaft by a taper lock bushing, shown in the cutaway view. In ordinary installations, a torque arm is fastened to a convenient stationary part of the machine. A clutch or bearing block designed as an integral part of the machine, may replace the torque arm. Standard pitch diameters used.

The reduction pulley assembly is entirely sealed, with all gears hardened steel, running in oil. Anti-friction bearings are used throughout. A clutch or an overload release can be furnished as extra protection, on special order.

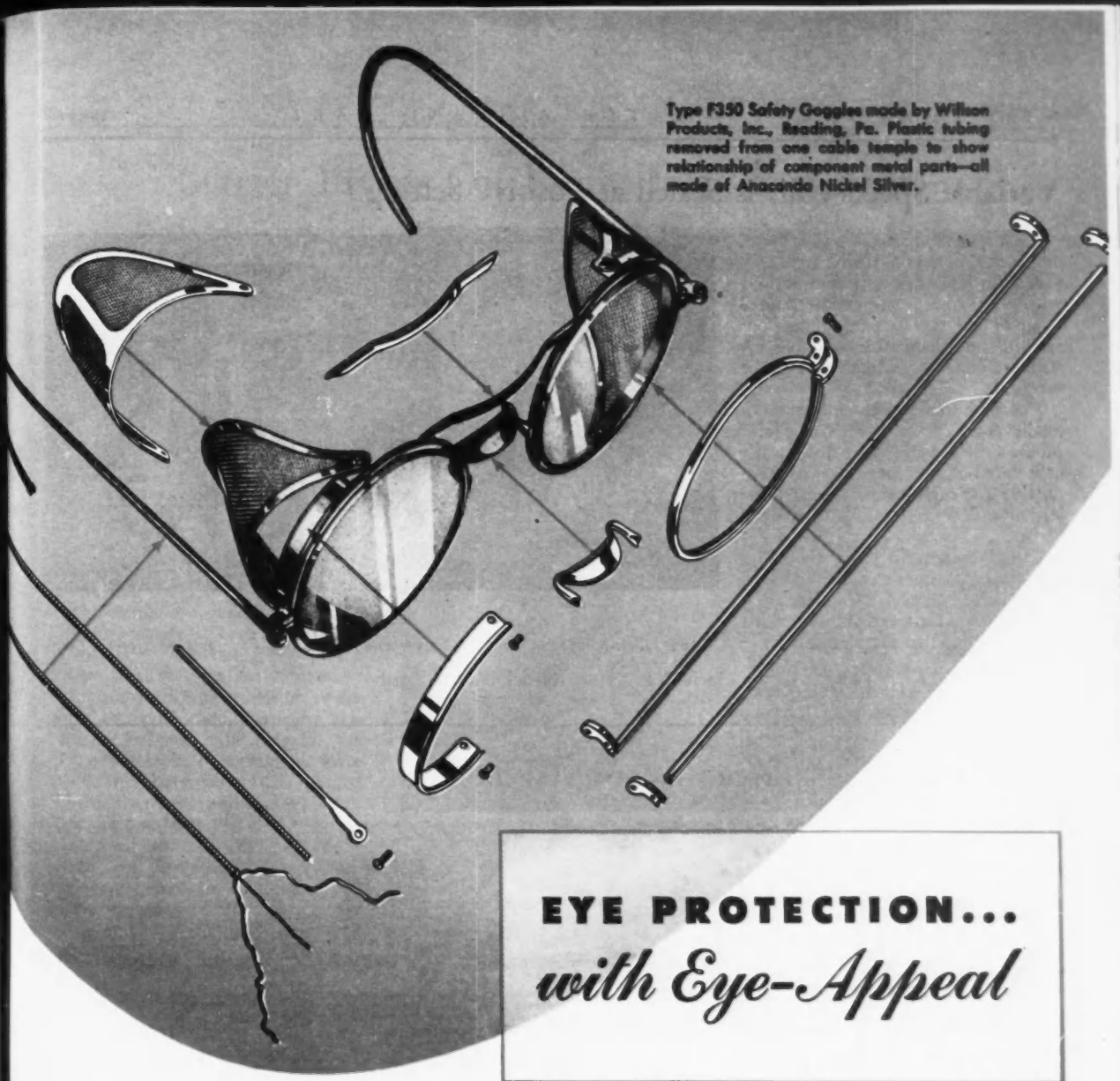
Hart Reduction Pulley Co., 2404 W. Clybourn St., Milwaukee 3, Wis.



REMOVAL OF the assembly side plate gives a view of the hub gear and its two rotating planets. Gears run in oil.

Circle No. 22 on Reader Service Card

CONTINUED ON PAGE 176



Type F350 Safety Goggles made by Willson Products, Inc., Reading, Pa. Plastic tubing removed from one cable temple to show relationship of component metal parts—all made of Anaconda Nickel Silver.

EYE PROTECTION... *with Eye-Appeal*

When a functionally efficient product possesses beauty—plus day in and day out serviceability—many of its merchandising problems are overcome.

The manufacturers of Willson Safety Goggles have found that Nickel Silver supplies this attractiveness and sturdiness in abundance. What's more, it provides an equally important third requirement—economy of fabrication . . . for Nickel Silver is one of the most workable metals available.

If the manufacture and sale of your product could be enhanced through this combination of clear-through beauty, ready workability and a longer service life—think in terms of Anaconda Nickel Silver. The American Brass Company can supply both the metal and the know-how, for each year it produces millions of pounds in all commercial forms, in all standard compositions, finishes and tempers. The address is Waterbury 20, Connecticut; in Canada, New Toronto, Ontario. 5065

ANACONDA *the name to remember*

in **NICKEL SILVER**

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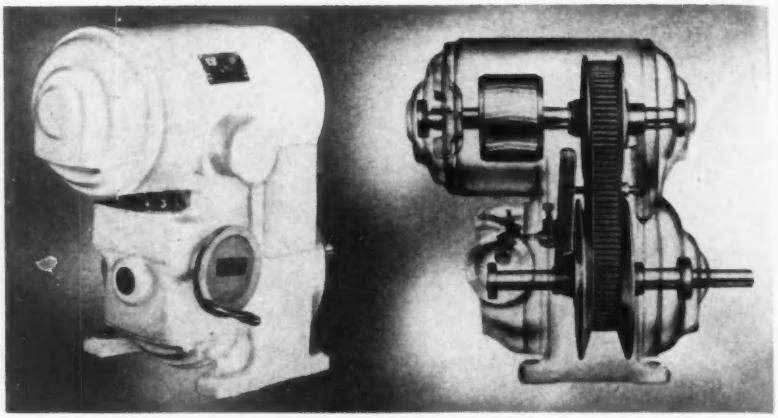
Variable Speed Unit is Sealed at Positive Setting

This variable speed, built-in V-belt motor line is now available with provision for sealing speeds at a positive setting or within any predetermined range of speeds. Mounting dimensions are still interchangeable with NEMA standard motors. A white finish can be supplied.

The new motor units are available totally enclosed, splash-proof or drip proof. Sealed ball bearings and the new speed sealing device make them suitable for high temperature pasturization and sanitary pumping applications.

Capacities range from ½ to 25 hp and maximum speeds extend from 26 to 2,000 rpm. Single and double gear-reduction variable speed units are available in addition to the type shown.



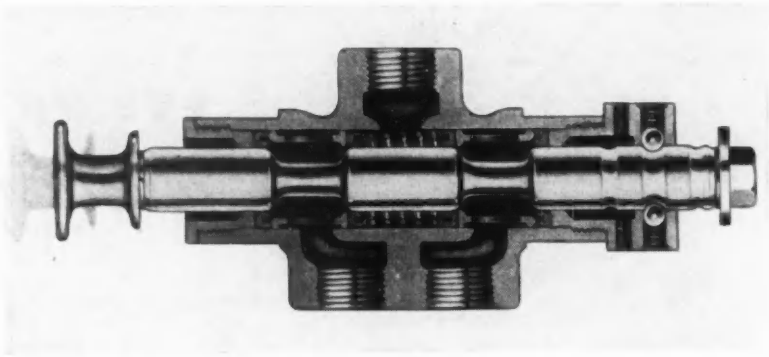
Sterling Electric Motors, Inc., 5401 Anaheim—Telegraph Rd., Los Angeles 22, Calif.

Circle No. 23 on Reader Service Card

Valve Blocks All Ports in Neutral Position

A line of neutral valves can be supplied for knob, lever, clevis and treadle operation. When the valve is in the neutral position, all ports are blocked. It is then possible to stop and hold the piston of a single or double acting cylinder in any position. The neutral position valve can be supplied normally open or normally closed, 3 or 4 way, with open end or piped exhaust. The valve is available in ¼, ⅜, ½, ¾ and 1 in. pipe sizes. Pressure range is from 0 to 175 psi.

Valvair Corp., 454 Morgan Ave., Akron 11, Ohio



Circle No. 24 on Reader Service Card

Crankcase Plug Gives Loose Part Warning

Metal parts circulating with the engine oil are trapped in this crankcase plug, closing an electric circuit and flashing warning lights on the instrument panel. Fitted at the bottom of the crankcase, the detector has a central electrode consisting of a silver plate with six holes grouped symmetrically around the center. Six separate electrodes nearly close the holes, leaving a gap sufficient to permit passage of oil, but blocking loose metal particles.

On the instrument panel are six warning lamps for each engine. The operator can judge by the number of lamps lit, and the rapidity of their lighting sequence, how serious the failure is. The detector also gives warning of incipient failures towards the end of a run.

The detector housing is solidly built, so no extra plug is needed for drawing off sump oil—it is simply screwed into the regular circulation outlet, and the oil pipe attached. Absence of moving parts means there can be no functional failure. It is operated on alternating current since direct current causes electrolysis of the oil. Electrical connectors built into the detector enable it to be quickly coupled.

G. Howard Smith, Brunkebergstorg 14, Stockholm, Sweden

Circle No. 25 on Reader Service Card

CONTINUED ON PAGE 177

Starter Pivots On Knife Edge Fulcrum

A line of across-the-line starters in NEMA sizes 0 through 4 for 110 to 600 volt, single and polyphase motors up to 100 hp is now being manufactured. A range of enclosures is provided for unusual conditions. Power wiring connects straight through the starter by pressure type screw-down terminals. Double break, spring loaded, silver contacts are inclosed in a removable arc quench box. All parts are removable from the front of the enclosure.

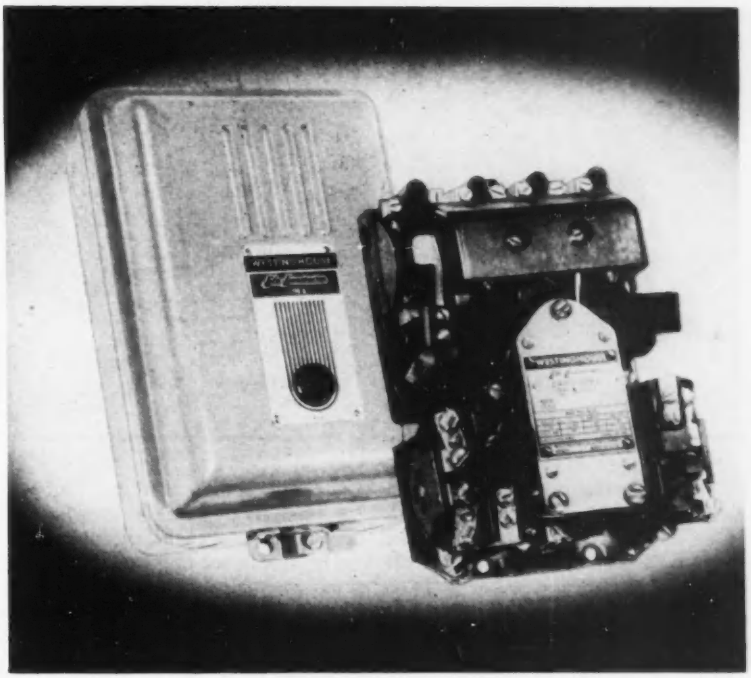
The moving element see-saws on a knife edge fulcrum. A vacuum impregnated coil attracts one end of the lever against the pull of the kick-out spring. The moving contacts at opposite side of the fulcrum are swung over to the stationary contacts. There are no sliding members. The spring provides a positive force to open the contacts.

The arc quenching provision is designed to reduce contact burning and pitting. As shown inthe diagram, the arc is drawn by its own magnetic force up into the plates, where it is divided into small segments and snuffed out in a half cycle or less.

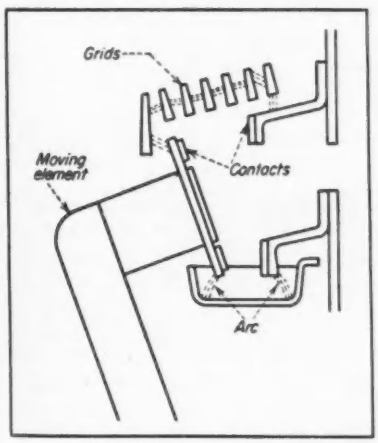
Overload protection is given by a bi-metallic, snap-action disk switch. The relay cannot be damaged by attempted reset at any time during the cooling period. Calibration is maintained. The relay can be adjusted to reset automatically or manually.

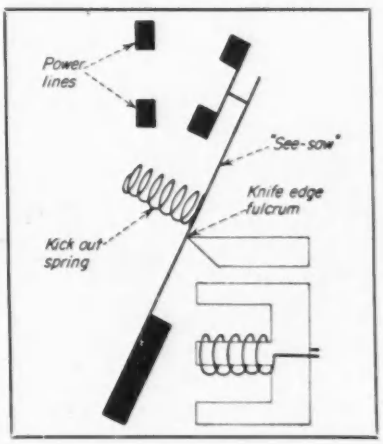
Three auxiliary contacts, or interlocks can be provided for complex circuits. This is in addition to the single interlock normally attached.

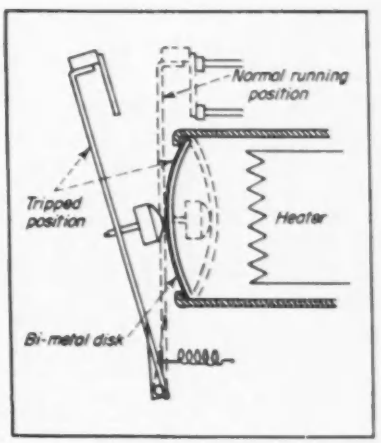
Westinghouse Electric Corp., P. O. Box 868, Pittsburgh 30, Pa.



Maximum Horsepower						Nema Size	8-Hour Continuous Volt Ampere Rating	
Polyphase Volts			Single Phase Volts				Enclosed	Unclosed
110	208-220	440-600	115	230	440-600			
1½	2	2	1	1½	1½	0	13.5	15
3	5	7½	1½	3	5	1	22.5	25
7½	15	25	3	7½	10	2	45	50
15	30	50	7½	15	25	3	90	100
25	50	100	....	....	....	4	135	150







Circle No. 26 on Reader Service Card

CONTINUED ON PAGE 178

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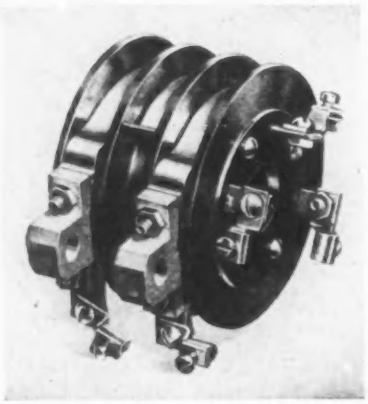
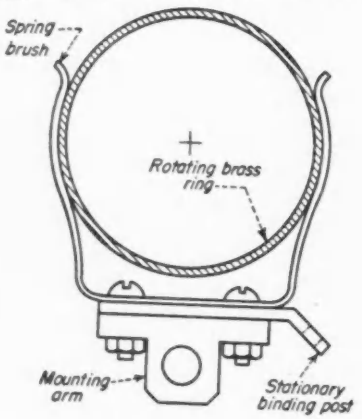
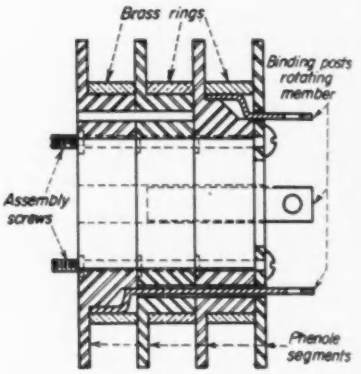
Collector Ring Feeds Current to Slow Speed Devices







This collector ring is offered for slow speed operation with currents up to 75 amps, at 220 v. It is intended for industrial and entertainment applications requiring a low-cost collector to supply current to rotating lights, instruments, and machines. This is not a high speed collector like those used on electric motors.

The unit is made up of phenolic segments held together by four brass screws. The rotating part may be mounted on a 1½ in. shaft or tube, or may be attached to a flat surface by the four assembly screws. Stationary binding posts connect to "U" shaped, spring alloy brushes. These ride on heavy brass rings connected to the rotating binding posts. The stationary brush springs each form an almost complete circle and maintain contact along a large surface on the rotating brass rings.

The insulating rings are 3¾ in. in diameter and the assembly is 2¼ in. long through the bore, exclusive of binding posts. Models can be furnished to carry 1, 2, 3 or 4 conductors.

Industrial Electric Wks., Dept. 133-E, 1509 Chicago St., Omaha, Neb.

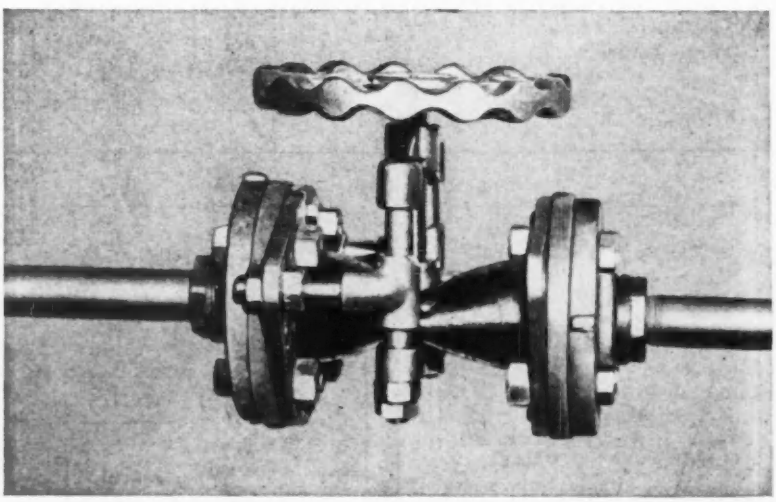
Circle No. 27 on Reader Service Card

Valve Pinches Rubber Neck to Stop Flow

A new rubber pinch valve is offered for use in the mining, paper, chemical, oil, food and beverage industries. The new unit is designed to replace metal valves in pipelines carrying abrasive or corrosive mixtures. Pipe misalignment is taken up by the rubber neck and no packing or repacking is required. Vibration and water hammer are absorbed and a positive seal is given in the closed position. The metal parts can be refitted to new rubber valve bodies when replacement is required. Galvanic action in metal lines is broken by the insulating rubber connection.

Bodies are available in abrasive and corrosive resistant compounds, neoprene for oil resistance, butyl rubber for heat and acid, and pure gum stock for food and beverages.

U. S. Rubber Co., Rockefeller Center, New York 20, N. Y.



THE NEW VALVE can be installed and serviced where space is limited. The rubber body is detached from the flanges for replacement when necessary. The whole valve is not discarded. Coal screenings, chips or concrete are handled.

Circle No. 28 on Reader Service Card

CONTINUED ON PAGE 180

IMPORTANT SAVINGS gained by Users of

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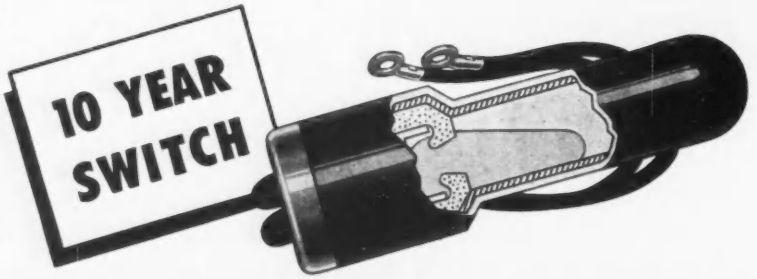

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Steel Durakool MERCURY SWITCHES

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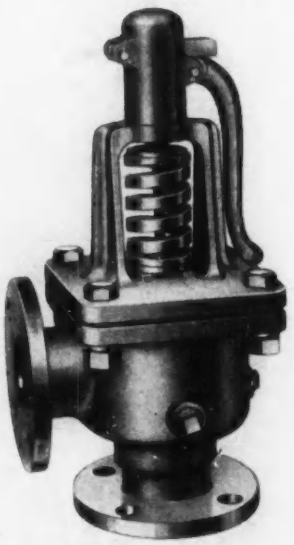
DURAKOOL, INC. • ELKHART, INDIANA

Navy Approves New Safety And Relief Valves

A line of cast carbon and alloy-steel safety and relief valves has been added to the bronze line which this company has manufactured since 1875. The new constructions include all types formerly manufactured by Star Brass Company.

The valve illustrated is cast carbon



steel with stainless steel trim for pressures up to 600 lb and temperatures to 650 deg F. Sizes range from ¾ to 6 in. with ASA standard flanged inlet or screwed outlet. The valves are NB certified, ASME tested and are Navy approved adaptations with high discharge capacity and close blowdown control, according to the manufacturer.

Kunkle Valve Co., 111 S. Clinton St., Fort Wayne 2, Ind.

Circle No. 29 on Reader Service Card.

New Black Oxide Process Offered

A two-component product is now offered for use in black oxide finishing processes. The first ingredient is a granular material which makes up the bulk of the bath and contains the correct amount of oxidizer and alkali, without an excess of either. The second component is furnished in compressed briquettes containing active oxidizers plus inhibitors which tend to reduce red and green stains on the work. Special agents to increase the speed, density and depth of penetration are also present.

The new process overcomes some

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KODAK CAMERA
WAS INVENTED

Koven

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EQUIPMENT PARTS

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Jacketed revolving drum made of stainless steel.

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L. O. KOVEN & BRO., INC.
154 Ogden Ave., Jersey City 7, N.J.

Plants: Jersey City, N. J. Dover N. J.

KOVEN FOR INDIVIDUALIZED EQUIPMENT PARTS SINCE 1881

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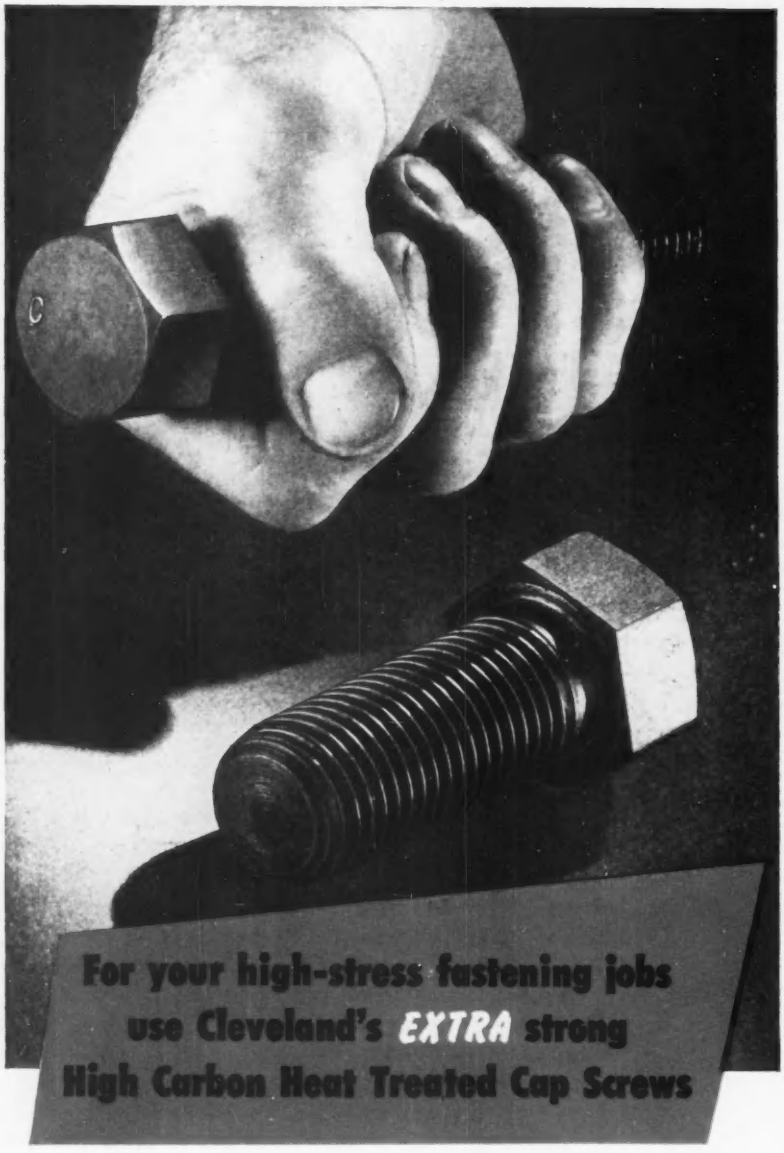

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CAP SCREWS, SET SCREWS, MILLED STUDS
Ask your jobber for Cleveland Fasteners

of the difficulties of the present single-component method. If the bath is weak, the operator can add the correct amount of oxidizer without increasing the alkali content. If alkali is required, on the other hand, the operator is able to restore the balance without overloading on the oxidizer at the same time.

The manufacturer claims that the finishing process can thus be controlled to operate at continuous efficiency. A more uniform and perfect coat at more economic cost is claimed for the new method over previous one-component black oxide finishers.

Heatbath Corp., Springfield, Mass.

Circle No. 30 on Reader Service Card

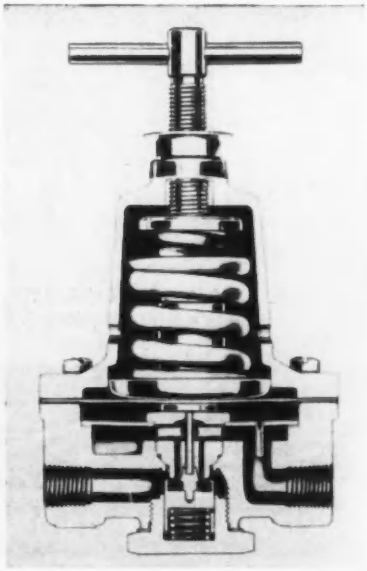
Pressure Regulator Reduces Line Pressures To 250 Psi

A new liquid pressure regulator is designed for handling water, oil and non-corrosive liquids up to 200 F, where close regulation of secondary pressure is desired.

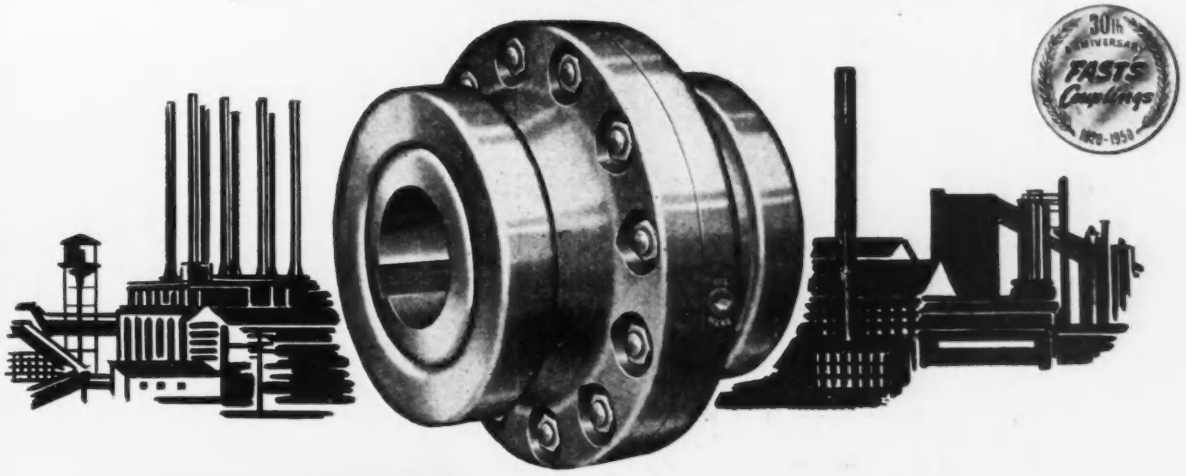
This regulator reduces line pressures up to 400 psi to working pressures of up to 250 psi in the following ranges: under 15 lb, 15 to 50 lb, 40 to 75 lb, 75 to 125 lb, 125 to 250 lb and 5 to 125 lb.

Unique features are the baffle plate and siphon tube action, which permits greater flow with less pressure drop. The regulator is claimed to respond rapidly to sudden demands for greater volume without excessive momentary pressure drop.

The regulators are compact, ranging in size from 6 to 9⅛ in. overall height. They are installed with in-line pipe



you can FORGET COUPLING SHUTDOWNS—



INDUSTRY REPORTS—

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THE ORIGINAL GEAR-TYPE

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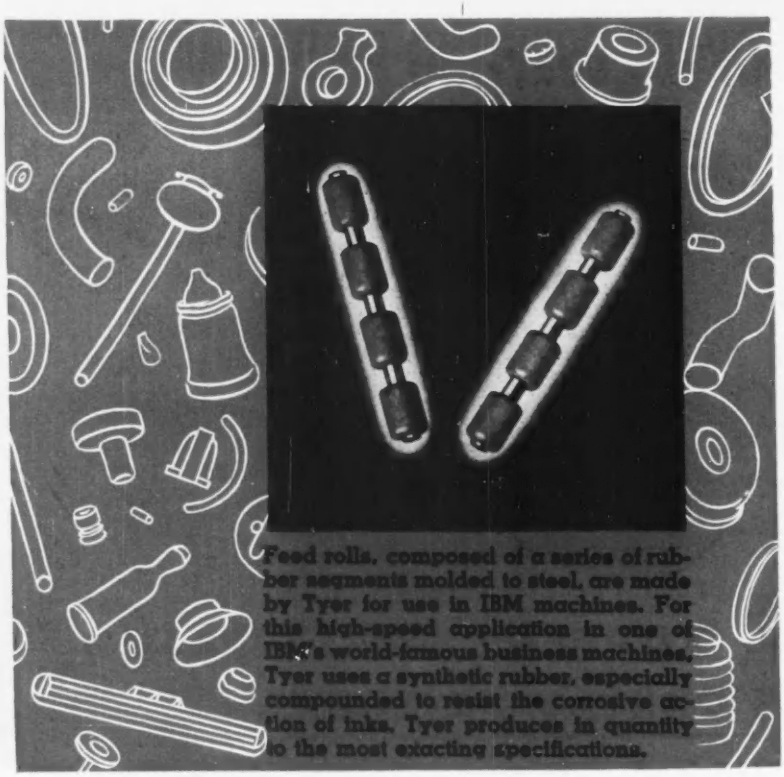
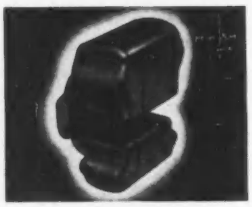


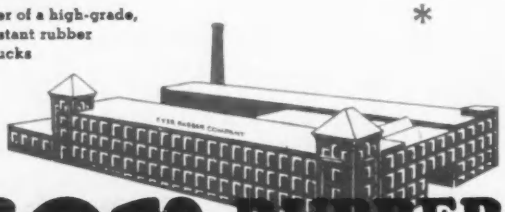
Feed rolls, composed of a series of rubber segments molded to steel, are made by Tyer for use in IBM machines. For this high-speed application in one of IBM's world-famous business machines, Tyer uses a synthetic rubber, especially compounded to resist the corrosive action of inks. Tyer produces in quantity to the most exacting specifications.

For 94 years Tyer has been doing remarkable things with rubber. Tyer originated WHITE RUBBER and ELASTIC WEBBING. Tyer's war products ranged from giant pontons to tiny earplugs made to a tolerance of one thousandth of an inch. Today Tyer leads in SERVICE to INDUSTRY. Many of the country's finest products have vital rubber parts made by Tyer. These famous manufacturers know that Tyer does unusual things with rubber.



If there is a rubber part in your product (old, new or proposed) Tyer technicians will give you the utmost cooperation in putting all Tyer's 92 years of experience at your service. Ask the Tyer representative. Write to us in Andover or to the nearest branch.

A shock insulator made by Tyer of a high-grade, resilient, oil and weather resistant rubber compound to protect heavy trucks from road shocks.



Tyer RUBBER COMPANY

* ANDOVER, MASSACHUSETTS

159 Duane St., NEW YORK 189 W. Madison St., CHICAGO 3-252 Gen. Motors Bldg., DETROIT

connections. Maintenance is simple because the regulator can be dismantled without removal from the line and all parts can be reached for easy replacement.

C. A. Norgren Co., 222 Santa Fe Dr., Denver 9, Colo.

Circle No. 31 on Reader Service Card.

Stone Lining Protects Steel Tanks

Steel tanks can be lined with $\frac{3}{8}$ in. thick hydraulic stone as protection against rust. The water is held by the stone lining and the steel tank merely resists pressure, with no contact with the water inside. The new tanks are slightly higher in cost than galvanized units, but are claimed by the manufacturer to be considerably lower in price than non-ferrous metal units.

The hydraulic stone lining is applied to the tank interior while in plastic form by a centrifugal process giving a uniform layer, $\frac{3}{8}$ in. thick. This compound hardens to form a water-resistant seal. It does not change the taste or color of the water. Because it has the same coefficient of expansion as the steel tank, the stone lining is not damaged by temperature changes. Due to the low heat conductivity of the material, heat losses are reduced.

The tank itself is made with convex heads welded over the shell. This design permits forming the hydraulic stone lining in a continuous arch, tight against the metal wall, so that it will not be damaged by handling. All tanks are testing at hydrostatic pressures of 300 lbs per square inch.

Sepco Corp., Pottstown, Pa.

Circle No. 32 on Reader Service Card.

Miniature Relay Saves Space

This miniature telephone relay is designed to save chassis mounting space. The new hermetically sealed unit with steel enclosures measures 1 x $1\frac{1}{16}$ x $2\frac{5}{32}$ in. high. Dimensions of the unhoused relay are $\frac{11}{16}$ x $1\frac{1}{2}$ x $1\frac{3}{8}$ in. long.

Especially developed for this series of relays, the enclosure illustrated will accommodate the relay with maximum contact stack and can be fitted with all headers except standard octal plug. Another enclosure, not illustrated, will take these relays with any header including standard octal plug. Hermetically sealed relays are desiccated at high temperature and sealed in one atmosphere of nitrogen in a design to

BANK ROBBERS *Terrorized*

Crime prevention aided by Telechron Timing Motors

Most bank robbers take no chances on a vault that can screech a warning of their presence.

In fact, official records of the Diebold Corporation — makers of Bank Vault Burglar Alarm Systems — show that robbers who have attempted such an attack were so panic-stricken by the alarm, they left their tools behind them, thus leading to their own identification and arrest! These same records also show that nearly 2000 successful bank robberies on unprotected vaults were committed between 1903 and 1948. During the same period, only 97 attacks were made on Diebold-protected vaults—none of them successful.

Because the Diebold Alarm System must perform unfailingly at all times, the Telechron Timing Motor is specified. It is *instantly, constantly synchronous* . . . gives *accurate* performance.

Are YOU Well Timed?

Perhaps you, too, need to depend upon a timing device that offers you split-second accuracy. If so, a standard Telechron Timing Motor is probably the answer for you. A Telechron application engineer, backed by the broadest experience in the field, can show you how you can save time and money with Telechron. Consult him *early* in your planning. Meanwhile, send the coupon below for further data. TELECHRON INC. A General Electric Affiliate.

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ALL TELECHRON TIMING MOTORS ARE

INSTANTLY . . . CONSTANTLY SYNCHRONOUS

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10 Union Street
Ashland, Massachusetts

Please send me information on sizes and types of Telechron Synchronous Motors. My possible application is:

Instruments	☐	Communications Equipment	☐
Timers	☐	Other (please fill in)	
Electric Appliances	☐	.....	
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Juke Boxes	☐	.....	
Air Conditioning & Heating Controls	☐	.....	

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Are you willing to gamble a 3¢ stamp

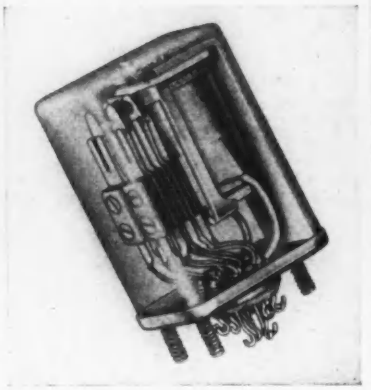
on lower unit costs for your product?

• JUST an ordinary 3c stamp may open the way to substantial savings for you—if you use it to send us an outline of your spring requirements. As they often have in the past, our skilled springmakers and practical, experienced engineers may be able to show you how you can reduce your spring costs and perhaps even make it possible to simplify assembly of your product. Accurate's unexcelled facilities and spring-making "know-how" are your best bet for the right spring for your job at the lowest overall cost. And we're prepared to show you the "proof of the pudding."

The sooner you "risk" that 3c stamp the sooner you'll be in line for the "pay-off." Why not do it TODAY?

Accurate Springs

ACCURATE SPRING MFG. CO.
3815 W. Lake St. • Chicago 24, Ill.
Springs, Wire Forms, Stampings



eliminate oxidation and reduce contact arcing.

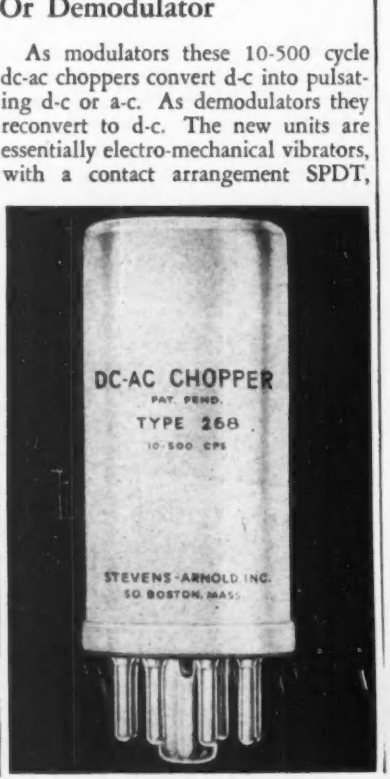
Featuring a dual stack with contacts of any arrangement up to 16 springs (8 per stack) with a limit of six movable poles, the unit is available with windings from a fraction of an ohm to 22,000 ohms or for operation up to 230 v either a-c or d-c. Minimum operating power is 0.050 watts per pole, allowing sensitivity of 1.5 ma, in a single pole relay. Maximum coil power for the unenclosed unit is four watts.

Potter & Brumfield, 274 N. Main St., Princeton, Ind.

Circle No. 33 on Reader Service Card.

Chopper Used As Modulator Or Demodulator

As modulators these 10-500 cycle dc-ac choppers convert d-c into pulsating d-c or a-c. As demodulators they reconvert to d-c. The new units are essentially electro-mechanical vibrators, with a contact arrangement SPDT,



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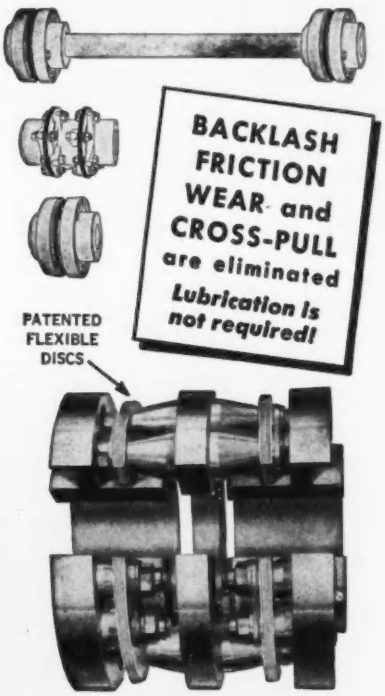

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NO MAINTENANCE PROBLEMS.
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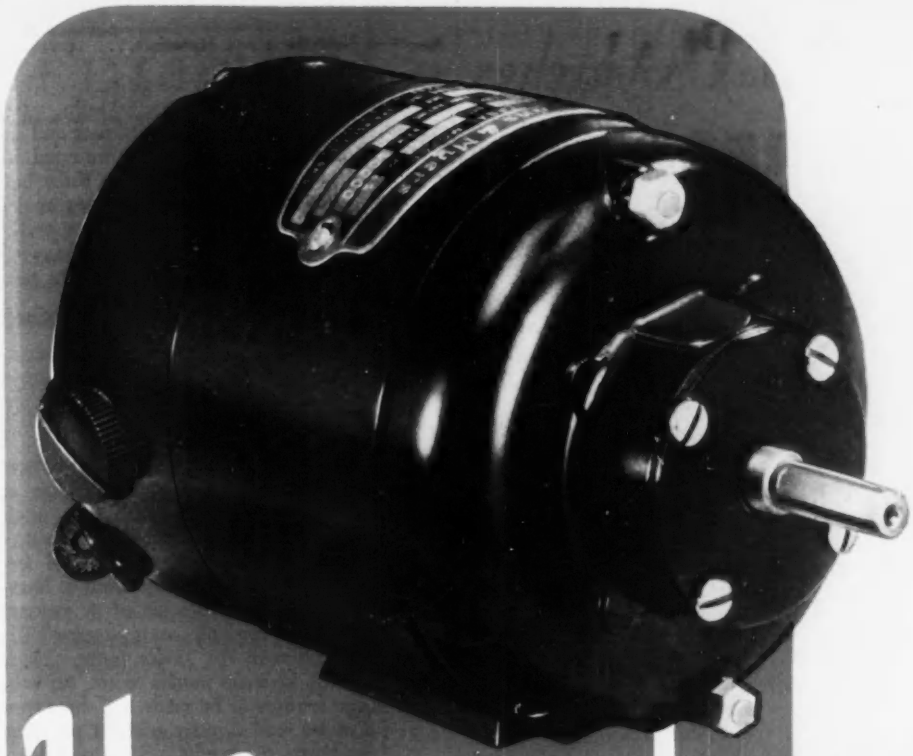

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● New R & M Universal Motors are something *you* should know about. To inherent *"series"* characteristics—high starting torque; high operating speed; adaptability to speed control—Robbins & Myers has added *many improvements* in performance and appearance.

BETTER, INSIDE AND OUT . . . From their dynamically balanced armatures to their rigid, welded-steel shells, *nothing* has been slighted. Commutation, brushes, bearings, insulation, and ventilation all represent progressive foresight, *backed* by long experience.

YOUR CHOICE . . In the range of 1/100 to ⅓ horsepower (covered by four frame sizes), there's the right motor for *every* "universal" service—sleeve or ball bearing; fixed rotation or reversible; open or totally enclosed; standard or special rating—and a *welcome variety* of housing types and end-heads.

GET THE FACTS ON THESE BETTER MOTORS . . . For quality motors with a *modern plus*, call in Robbins & Myers. Literature on request. And, if you would like to have R & M sit-in on a discussion of *powering improvements*, that's yours for the asking, too. R & M motors are *good* motors. Address Dept. P-70.

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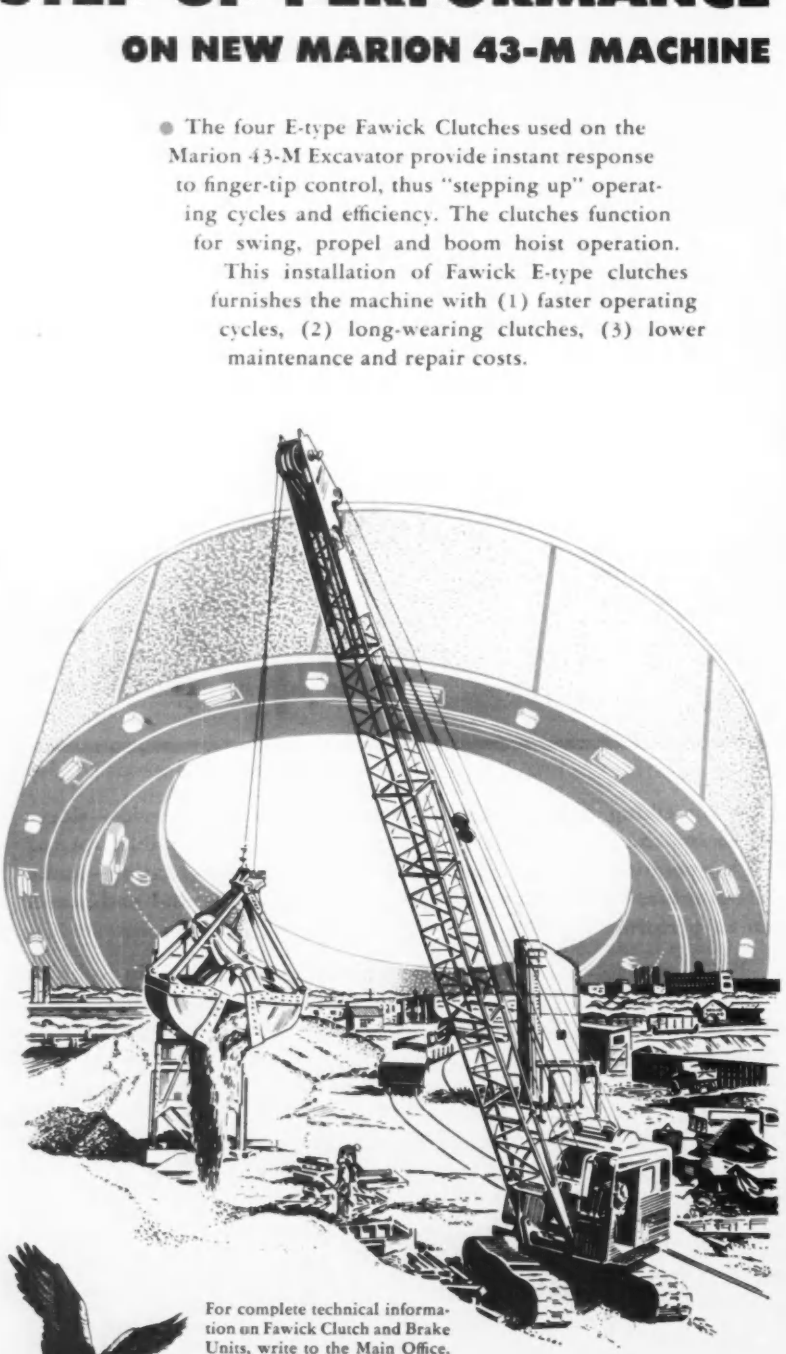
STEP UP PERFORMANCE

ON NEW MARION 43-M MACHINE

● The four E-type Fawick Clutches used on the Marion 43-M Excavator provide instant response to finger-tip control, thus "stepping up" operating cycles and efficiency. The clutches function for swing, propel and boom hoist operation. This installation of Fawick E-type clutches furnishes the machine with (1) faster operating cycles, (2) long-wearing clutches, (3) lower maintenance and repair costs.



For complete technical information on Fawick Clutch and Brake Units, write to the Main Office, Cleveland, Ohio, for Bulletin 300.

FAWICK Airflex CO., INC.
9919 CLINTON ROAD CLEVELAND 11, OHIO

FAWICK CLUTCHES = + + + = PEAK EFFICIENCY
AXIAL CONTACT 360° RADIAL CONTACT SHOCK ABSORPTION CONTROLLED TORQUE

break before make, in air.

Nominal ratings are 10 volts, 0.001 amp, d-c. The steel container and the electrostatic shield are connected together and brought out to three base pins. Phase shift approximates 50 deg at 60 cycles and 110 deg at 400 cycles.

Stevens-Arnold, Inc., 22 Elkins St., South Boston 27, Mass.

Circle No. 34 on Reader Service Card.

One Dial Controls Microwave Signal Source

A series of microwave signal sources are available, covering the range of 634 to 8,340 MCS with four units. These reflex klystron signal sources are controlled by one dial and frequency is read directly from a linear indicator to accuracies of ½ percent. The reflector voltage is automatically tracked with the cavity tuner. There are no klystron modes to set, no voltage settings to be made and frequency can be read directly without resorting to charts or graphs.

Non-contacting shorts are used to eliminate noise and reduce mechanical wear. Terminals are provided for applying modulation to either the grid or reflector. The signal sources are supplied complete with tube.

Polarad Electronics Corp., 100 Metropolitan Ave., Brooklyn, N. Y.

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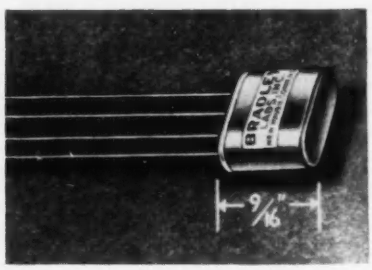
Tiny Rectifiers Are Hermetically Sealed

Hermetically sealed copper oxide rectifiers are offered for instrument uses. Supplied for conventional bridge, center top, half wave circuits or as balanced and matched units for modulators and related equipment, the new midget rectifiers are rated up to 6 v a-c and 5 ma d-c. Four tinned leads are supplied. The sealed container is 11/16 by 9/16 by ¼ inches.



Bradley Laboratories, Inc., 82 Meadow St., New Haven, Conn.

Circle No. 36 on Reader Service Card.

MEETINGS

July 5-21

PRODUCT DESIGN SEMINAR sponsored by Lehigh University and the Society of Industrial Designers, Bethlehem, Pa.

July 12-14

INSTITUTE OF AERONAUTICAL SCIENCES—Annual Summer Meeting. I.A.S. Western Headquarters Building, Los Angeles, Calif.

July 28

MALLEABLE FOUNDERS' SOCIETY—Western Sectional Meeting, Drake Hotel, Chicago, Ill.

August 7-19

FIRST U. S. INTERNATIONAL TRADE FAIR—Coliseum Arena and Navy Pier, Chicago, Ill.

August 14-18

SOCIETY OF AUTOMOTIVE ENGINEERS—West Coast Meeting, Biltmore Hotel, Los Angeles, Calif.

August 14-16

NATIONAL ASSOCIATION OF POWER ENGINEERS—National Power Show, Jefferson Hotel, St. Louis, Mo.

August 16-18

THIRD WESTERN PACKAGING AND MATERIALS HANDLING EXPOSITION—Civic Auditorium, San Francisco, Calif.

August 23-26

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS—Pacific General Meeting, Fairmount Hotel, San Francisco, Calif.

September 8-9

SYMPOSIUM ON PLATICITY sponsored by the Graduate Division of Applied Mathematics, Brown University, Providence, R. I.

September 18-22

INSTRUMENT SOCIETY OF AMERICA—Fifth National Instrument Exhibit, Memorial Auditorium, Buffalo, N. Y.

September 23-26

PACKAGING MACHINERY MANUFACTURERS INSTITUTE—18th Annual Meeting, The Homestead, Hot Springs, Va.

September 26-29

ASSOCIATION OF IRON AND STEEL ENGINEERS—Iron and Steel Exposition, Public Auditorium, Cleveland, Ohio.

Lufkin

You can have a copy of this valuable 48-page catalog—

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Dependable Product Performance

This Catalog, with the tremendously helpful information contained in its 48 pages, can be of great value to you. Numerous pages of photographs show LUFKIN Gears in the service of various industries, such as the oil industry—one of the toughest for gears. Photos of the various type Reducers and Increasers are shown with complete specifications. Pages are devoted to a "guide for selecting character of load" and a "service factors table." There are a number of pages on "selection of gear reducers." Horsepower rating tables are given as well as pages on load capacities and pages showing general dimensions. All this with other pertinent gear details make this catalog a dependable aid in your planning.

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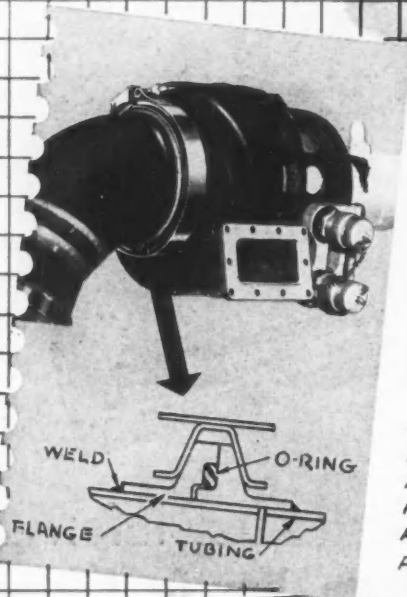

QUICK COUPLING FOR TURBINE DUCT

MARMAN V-BAND COUPLING WITH QUICK COUPLER LATCH PROVIDES LIGHT-WEIGHT POSITIVE SEAL WITH FAST ASSEMBLY AND DISASSEMBLY.

DESIGNED FOR USE ON ROLLED OR MACHINED FLANGES.

SPECIAL GASKETS AVAILABLE TO ACCOMMODATE VARIOUS HIGH P.S.I. AND TEMPERATURE REQUIREMENTS.

Photo courtesy Airesearch.

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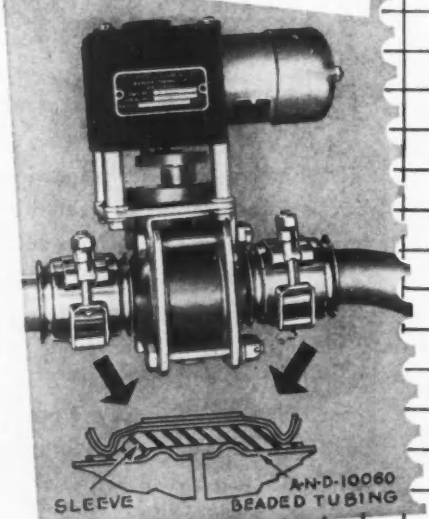

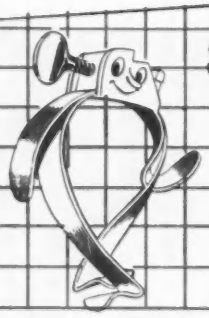

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INGLEWOOD, CALIFORNIA

OUR READERS SAY

Still More on Gear Trains

To the Editor:

In the April 1950 issue of PRODUCT ENGINEERING on page 200 you published a letter by W. W. Johnson of Cleveland, Ohio in which he presents a ratio that cannot be approximated by the continued fraction method. I have used this method for several years and have always been able to find a suitable gear train for the required ratio.

The ratio 251/93, which Mr. Johnson proposes, closes out with only five principal convergents. He examined the area between the fourth and fifth principal convergents and found no suitable factor.

Having failed to find suitable factors between these two principal convergents, we can take the last convergent and expand it by multiplying numerator and denominator by the same whole number, thus arriving at a new fraction that will not be satisfactory. However, we can search in a new area on the factor table by subtracting the fourth principal convergent from our new fraction not more times than there are intermediate convergents between the fourth and fifth principal convergents.

Examination by this system readily gives at least three satisfactory ratios, which are:

$$\frac{(251 \times 21) - 27}{(93 \times 21) - 10} = \frac{5244}{1943} = 2.698919$$

$$\frac{(251 \times 27) - 27}{(93 \times 27) - 10} = \frac{6750}{2501} = 2.698920$$

$$\frac{(251 \times 17) - (27 \times 3)}{(93 \times 17) - (10 \times 3)} = \frac{4186}{1551} = 2.698904$$

It will be noted that the second example is accurate in the fifth place to the ratio 2.69892 given by Mr. Johnson.

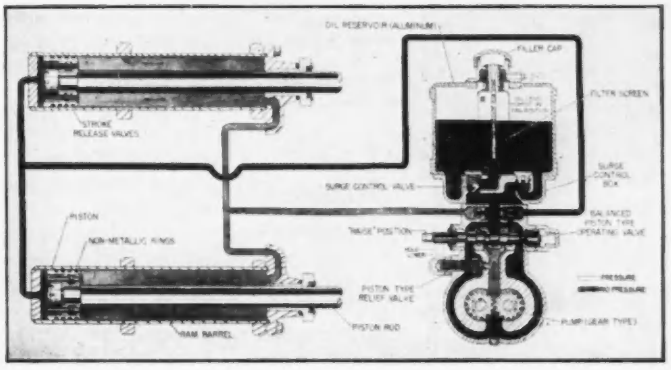
—P. R. NOLING
Rockford, Illinois

Dimensioning Involute Gears

To the Editor:

"Dimensioning Involute Gears on Manufacturing Drawings" is a rather misleading title to my article in your May number. The criticisms I have received to date from my friends in the gear industry all revolve around the proposition that the shop man

Good Equipment Made Still Better with LaPLANT-CHOATE HYDRAULIC UNITS



Top Performance Built into Bros Dozers with LPC Hydraulic Units

FOR their *Power-Plus* Bulldozer, Bros engineers wanted speed and power for fast work under heavy loads . . . instant response to controls . . . simple, compact design . . . trouble-free operation. A complete LaPlant-Choate Hydraulic System consisting of jacks and the famous "packaged" hydraulic fluid power unit, was chosen to meet all requirements . . . to make their *good* product still *better.*

Design Your Product for Better Performance

Whatever your problem, you'll get more efficient operation, simpler design and greater sales advantages for your product when you use LaPlant-Choate Hydraulic Units as standard equipment. Here are some of the features that will make your product better — *Compact Design* with pump, control valve, relief valve and reservoir contained in one simplified unit; *Versatile Application* on any type of machinery or equipment; *Multiple Use* of one installation with multiple valves, combinations and oil circuit variations; *Positive Fingertip Control* results in a high degree of operating accuracy and precision; *Easily Installed* and adaptable to a wide choice of mountings; *Low Maintenance* and *Long Life* under the most adverse operating conditions.

Write for complete information about making your products easier to design, manufacture, sell and service. Ask for Bulletin B-1152B LaPlant-Choate Manufacturing Co., Inc., Cedar Rapids, Iowa.

THE LaPLANT-CHOATE FAMOUS FLUID POWER CONTROL

Pump, valve and oil reservoir are all combined into a single compact unit that mounts on the front of the tractor behind the radiator guard. This new "closed system" design completely eliminates long suction lines, reduces the hazard of leaks and assures greatly increased speed and efficiency. In addition, the entire unit is skillfully engineered and precision built for utmost simplicity, easy servicing, and long, trouble-free operation.

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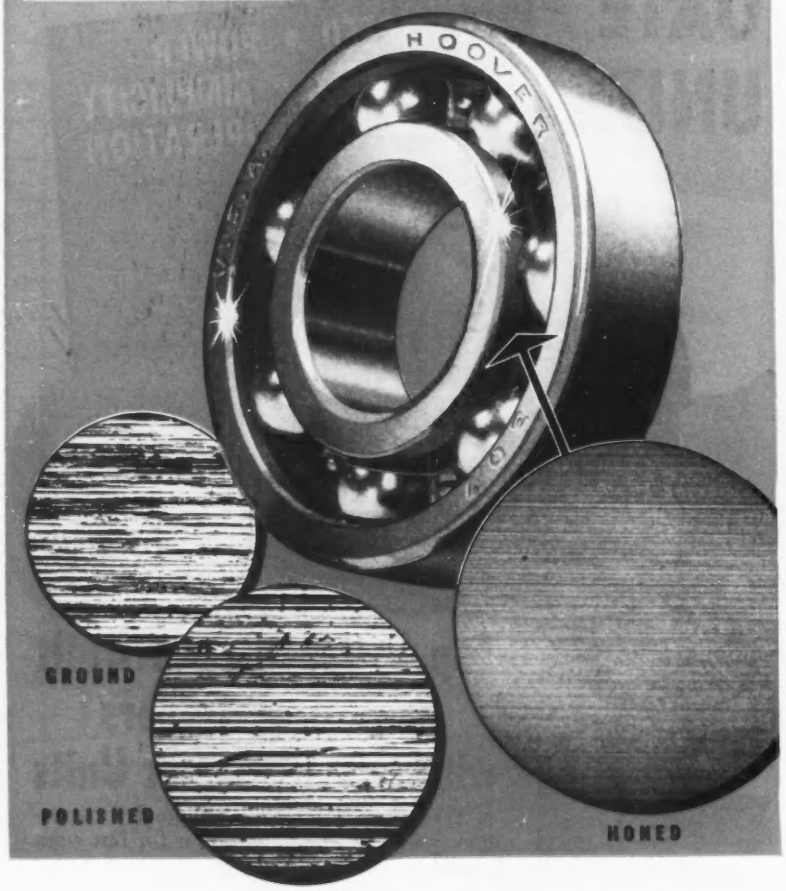
HONED RACEWAYS



exclusive with
HOOVER BALL BEARINGS

The photographs reproduced above are magnified one hundred times so you can see the difference between ground, polished and honed raceways. The process and the special machines for the honing operation are exclusive, patented, Hoover developments. Honing by Hoover goes far beyond grinding and polishing to achieve a surface that assures amazing quietness plus *90 per cent longer bearing life . . . 30 per cent greater load capacity.* That's why Hoover Ball Bearings are the choice of distinguished American manufacturers of fine machines and equipment.

The Hoover Engineering Manual will be mailed free to engineering and purchasing executives requesting a copy on their business letterhead.

THE ARISTOCRAT OF BEARINGS

HOOVER BALL and BEARING CO.
Ann Arbor, Michigan

would not understand the gear data in the form suggested.

I heartily agree. The purpose of this article was to show that basic dimensions do exist on involute gears, that they can be specified with appropriate tolerances and that a system can be inaugurated wherein all given dimensions are independent of other given dimensions.

At this stage, I do not recommend that anyone send his gear drawings through with only the data set forth in my article. However, I do recommend that this information be placed on the drawing and considered as basic. Diametral pitch, pitch diameter, pressure angle, base circle and so on may be added as desired as reference dimensions, and so marked. As the men in the shop become accustomed to the new form, the need for the old reference dimensions will wane until they will simply atrophy and fall completely out of use. Fundamentally, it is easier to select a tool to cut a 0.2706 base pitch than to find one for a 10.6534 diametral pitch with a 23.-4356 deg pressure angle! Yet these are the extremes to which our present dimensioning system has carried us.

Perhaps the purpose of my article would have been clearer to the readers if my original title had been retained. It was "Why Not Simplify Involute Gear Dimensioning?"

—SYDNEY L. TERRY

Webster Is Right

To the Editor:

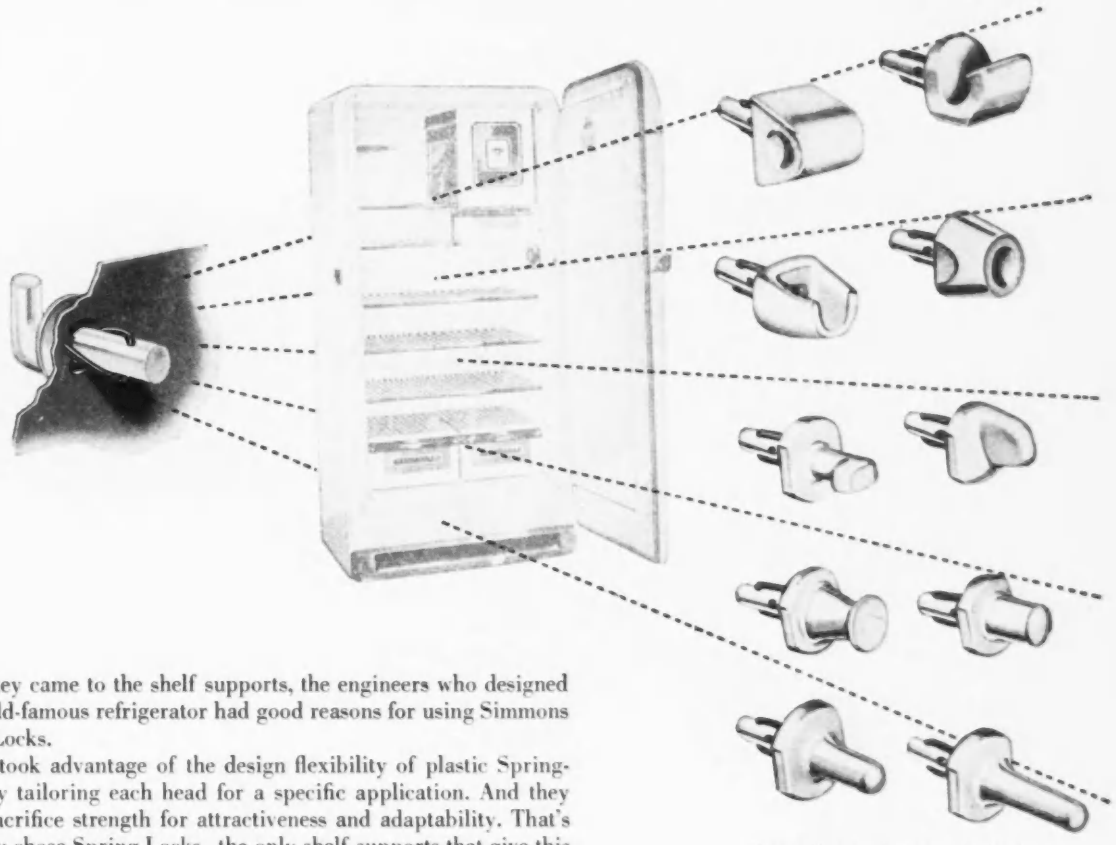
At one of our weekly engineers' conferences, I was called to task when I stated that Dr. Karl Compton is chairman of the Research and Development Board. If I am mistaken, who is the present chairman?

—WILLIAM ALLEN
Galveston, Texas

Ed.—William Webster, executive vice president of the New England Electric System Boston, Massachusetts, has been nominated by President Truman and approved by the Senate to head the Defense Department's Research and Development Board. He succeeds Dr. Karl Compton who resigned because of ill health.

Mr. Webster served eight years in the Navy and received special training in Naval architecture at Massachusetts Institute of Technology. In World War II he served as consultant to the Office of Scientific Research Development. During 1948 and 1949, he was assigned to the National Military Establishment in Washington as assistant to the Secretary of Defense. He is

Look what's back of these plastic refrigerator shelf supports



Ten different designs of plastic Spring-Lock shelf supports, used by one of the world's largest refrigerator manufacturers.

When they came to the shelf supports, the engineers who designed this world-famous refrigerator had good reasons for using Simmons Spring-Locks.

They took advantage of the design flexibility of plastic Spring-Locks by tailoring each head for a specific application. And they didn't sacrifice strength for attractiveness and adaptability. That's why they chose Spring-Locks—the only shelf supports that give this combination of advantages:

- Spring-Locks may be designed with any shape head—for any application.
- Spring-Locks are the *only* plastic shelf supports with *steel inserts* to carry the load—give extra strength at the critical points of load or impact.
- Spring-Locks cut material and assembly costs. No nuts, bolts or threadings. Just a half-turn locks them securely.

Use Spring-Lock also as a lifter knob...a door strike...a blind rivet... as hundreds of different fastening devices, *either in metal or plastic.* We'll be glad to work out the details of your application with you.

SIMMONS FASTENER CORP. · 1751 North Broadway, Albany 1, N. Y.

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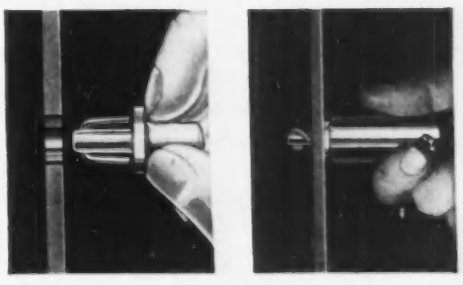
THE ONLY PLASTIC SHELF SUPPORT WITH A HEART OF STEEL



Here's how it operates: 1. Insert fastener. 2. Half-turn locks it securely. Steel insert extends through entire piece—increases load-carrying capacity of assembly.

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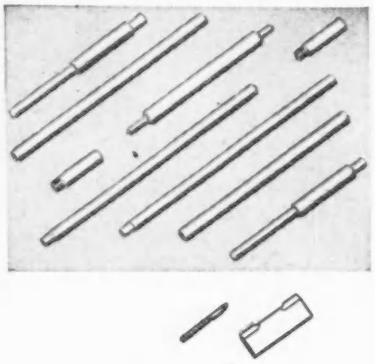

Low cost for precision quality, fine finish, uniform heat treatment is assured by our high productive capacity and special equipment.

Typical of a wide variety of parts are special rollers, shafts, studs, dowel pins made to order. Chamfer, radius, taper, hemispherical and other styles of ends. Rollers from .014" to .500" diameter. Centerless ground .040" to .500"; diameter tolerance ±.0001". Finish as fine as 3 micro-inches. Dowel pins from .0625" to .3125".

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TORRINGTON NEEDLE BEARINGS

chairman of the New England Council Atomic Energy Committee and a consultant to the National Atomic Energy Commission.

A second appointment to the ranks of research agencies in Washington is that of Rear Admiral Byron H. Hanlon as commander of the Naval Ordnance Laboratory at White Oak, Maryland. He replaces Rear Admiral Frank E. Beatty.

"Coffee-Maker" Steel

To the Editor:

Not long ago, I heard on the radio a brief announcement of a new steel making process that is considerably more rapid than present methods. Could you give me the name of the process along with any information regarding it? —S. H. C.
Columbus, Ohio

Ed—The new so-called turbo-hearth process for making steel is capable of making open hearth-quality steel in 12 min without using external fuel. This fast steel-making process is largely a development made at the Battelle Institute with the support of Carnegie-Illinois. The researchers first made thirty-two 1,000-lb heats of steel in a laboratory experiment at Battelle. Then, commercial-scale heats were made at Carnegie-Illinois in a 30-ton vessel loaned by Jones & Laughlin Steel Corporation.

In this process, heat is provided from chemical reaction by burning the impurities in liquid iron with a blast of air. In the turbo-hearth, the air is applied from the side, at the surface of the hot metal charge.

The development is considered especially important because it provides a steel-making method that is fast yet flexible. Oxygen can be added to the air if increased reaction speed is desired.

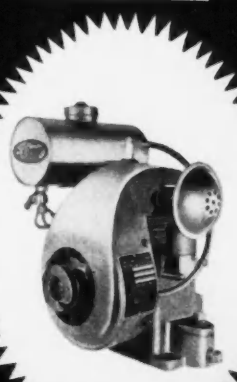
The vessel in which the process is carried out is a partly closed chamber. Its shape is somewhat like a giant coffee-maker, built of heavy steel sections and lined with basic brick that can stand temperatures ranging higher than 3,000 Fahrenheit.

Beware of Liberal Tolerances

To the Editor:

With the Armed Forces sending out educational orders, it might be well to warn some of your readers that the seemingly liberal tolerances on many Ordnance pieces are deceptive because, unless special care is taken, the manu-

choose



THE LAUSON Long Life ENGINE

ILLUSTRATED:
■ Lauson's new bantam beauty — Model LMH. Weighs only 22 lbs.! 1 HP. Other sizes to 6 HP. All Lauson engines are 4-cycle, air-cooled!

• Insist on Lauson — the engine that's *first in quality!*
Here are just a few of the superior construction features which make Lauson the Long-Life engine: Connecting rods have replaceable crank-pin bearing liners.

• Precision ball bearings on both ends of crankshaft.

• Fly-ball governor running in oil.

• Automotive-type float feed carburetor.

• Lauson original design provides direct stream of cool air over both valves simultaneously.

• Always choose Lauson engines — a better buy because they're better built!

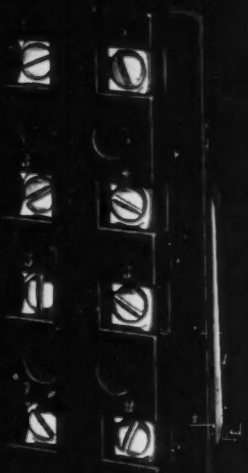
The LAUSON Company
Dept. PE, New Holstein, Wisconsin
A Division of Hart-Carter Company
In Canada: Hart-Emerson Ltd., Winnipeg, Canada

Now... At Last!...

PLATE CIRCUIT POWER RELAY

NEW CLARE RELAY IS TWO RELAYS IN ONE

Side view of typical CLARE Type "CP" Power Relay.



Front view showing convenient terminal arrangement.

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It takes one watt or more to operate an ordinary power relay; hence, it has to be operated from a sensitive relay or a high-current tube. This new Type "CP" Power Relay, truly two relays in one, will operate on less than 200 milliwatts—with, for example, a 6,500-ohm coil. Will operate in the plate circuit of any triode, including miniatures. Simplifies equipment; saves money and space; will outwear several ordinary power relays.

SALIENT FEATURES

Sensitivity. Pickup current can be as low as 3 milliamperes—with a 12,000-ohm coil.

Marginal operation. Dropout current can be as high as 58% of pickup current.

Heavy load capacity. D. P. D. T. contacts conservatively rated at 10 amperes, 230 volts, a-c; proved by one million operations at 30 amperes inrush, 10 amperes break.

No contact bounce.

Interlock contacts. A single-pole interlock can be provided, if required.

Fast operation. Operate time can be as low as 30 milliseconds.

Heavy insulation. Minimum of one-half inch creepage over exposed areas.

Convenient terminal facilities. Screw terminals recessed in terminal block in orderly array. No separate terminal board needed.

Versatile mounting. Front, back, or surface mounting.

Long mechanical life. 25 million operations, without readjustment.

Long operational life. One million operations at rated contact load, without readjustment.

No pigtails to break. On test, the long flexible contact springs have exceeded by 100 times the normal life expectancy of pigtail connections, commonly used on power relays.

Wide choice of coils. Like other Clare relays, this relay is custom-built to fit the application. Our engineers can choose from hundreds of different coil specifications the one best suited for the job.

For complete information send for Clare bulletin No. 113

CLARE sales engineers are at your service to help with your individual relay problem. Located in principal cities, their expert knowledge of relay problems is readily available. Look in your classified telephone directory or address: C. P. Clare & Co., 4719 West Sunnyside Ave., Chicago 30, Ill. In Canada: Canadian Line Materials Ltd., Toronto 13. Cable address: CLARELAY.

CLARE RELAYS...

First in the Industrial Field

The SPECIAL material for your shim* requirements...

LAMINUM *looks like solid metal, but it's actually made up of .002 or .003 inch layers of first quality shim stock, metallically bonded together. Peels easily with a penknife.*

LAMINUM, the metal that peels, comes in a wide range of thicknesses and laminations. Here is the basic information on this versatile, money-saving material.

STANDARD STOCK 8" x 48" SHEETS
BRASS AND STEEL

Gauge	.002 inch laminations	.003 inch laminations
.006	x	
.008	x	
.010	x	x
.016	x	x
.020	x	x
.032	x	x
.048	x	x
.062	x†	x†
.094††	x†	x†
.126††	x†	x†

†Also available as half laminated brass and half solid brass.
††Available in brass only.

PROPERTIES & SPECIFICATIONS

BRASS – Raw material is a commercial half hard high brass conforming to Federal Spec. QQ-B-611a, Comp C, half hard (5/27/44). The *laminated* brass conforms to Navy Aeronautical Spec. S-122, Aeronautical Material Spec. AMS-4508, Navy Ordnance Spec. 47B6.

STEEL – The raw steel used in LAMINUM conforms to Federal Spec. QQ-S-636, Condition 2, as well as SAE-1010. There are no government specifications on the finished steel LAMINUM.

Normally all LAMINUM stampings are made by us to our customers' specifications. However, for repair and maintenance work, some of our standard stock is available from your industrial distributor.

SHIM SIZE IS VIRTUALLY UNLIMITED

We've made some shims as large as 102 inches across—and others as small as your fingernail. With special joints developed over the years, we can make any size LAMINUM shim you want.

Other than standard thicknesses and lamination arrangements can be supplied upon special order.

BABBITTED SHIMS PREVENT OIL PRESSURE LOSS

Shims for use in split bearings can be fitted with babbitt lugs to prevent oil pressure loss without shaft scoring.

LET OUR ENGINEERS HELP YOU... We've been designing shims for 37 years. Why not throw that problem of yours at us? There's no obligation, of course.

SEND TODAY
FOR OUR ENGINEERING DATA FILE with all the quick facts on LAMINUM plus a free sample for your inspection.

***LAMINUM is used primarily for shims. But these facts may spark other thoughts that we'd be happy to help you develop.**

LAMINATED SHIM COMPANY, INC.
1407 UNION STREET GLENBROOK, CONN.

CUSTOM SHIMS

STAMPINGS

SHIM STOCK

AN·COR·LOK NUTS

facturing variations add up unexpectedly to make parts inoperative.

Our sad experiences at Westinghouse years ago led to formulation of the following procedure in making rifles and machine guns. It still seems worth repeating.

On all individual parts and subassembles, sketch out

"Acceptance" and "Rejection" gages.

"Acceptance" gages assure that parts will assemble and function without interference.

"Rejection" gages establish the other limits and prevent too much clearance. Each "rejection" gage checks only one dimension.

With these gages in mind, proceed with each part as follows:

1—Determine locating points.
Avoid using any important point which requires a second cut or grinding.

2—Work out machining operations.
A. Avoid adding tolerances.
B. Gage and cut from identical points.
C. Group similar machines.
D. Following cuts should remove burrs made by preceeding cuts.

3—Establish "Block inspections" after every few operations. These are 100 percent inspection points and may be the basis for bonuses to the operators in each block.

4—Outline final soft inspections.

5—Outline final inspection and test.

—D. DOUGLAS DEMAREST
Port Washington, Long Island

Where Can I Get It?

Tungsten and Germanium

To the Editor:

In the "Highlights" section of the May 1950 issue of PRODUCT ENGINEERING there are two items on which we wish additional information. On page 3, tungsten-iridium thermocouples for high-temperature applications are mentioned. On page 7, the use of partially activated germanium in radiation counters is mentioned.

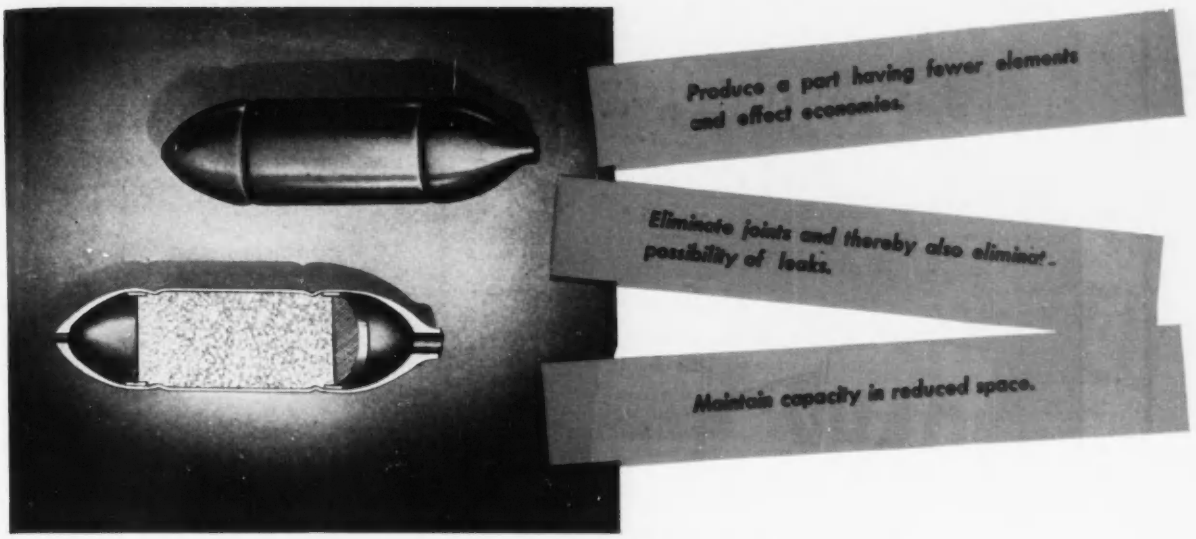
Speaking generally, we find that we read the capsule paragraphs in "Highlights" more carefully and thoughtfully than any section in the other technical magazines we regularly receive.

D. M. NIELSEN
Loudon Instruments, Inc.

Ed—Both of the items mentioned by Mr. Nielsen are the results of research work. Dr. W. C. Troy of the Armour

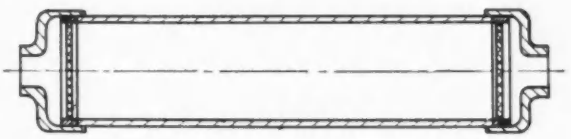
This can happen to you

Changes can be made in some functional component of a complete operating unit you are making that can mean economies and sales benefits . . . . Taking a case out of our files—here's a manufacturer, drawing on our extensive background, made a change in design and production of a dryer that brought about worthwhile advantages . . . . The development enabled him to . . . .


Produce a part having fewer elements and effect economies.
Eliminate joints and thereby also eliminat.. possibility of leaks.
Maintain capacity in reduced space.

The photo shows the streamlined, efficient part as it is now produced. Reference to the diagrams makes the advantage obvious.

OLD WAY:



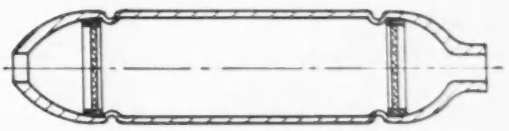
Material:

1. Seamless copper tube
2. End caps
3. Screen retainer units
4. Silica gel charge

Operations:

1. Assemble screen retainer and cap to one end
2. Fill with silica gel charge
3. Assemble screen retainer and cap to other end
4. Braze

NEW WAY:



Material:

1. Seamless copper tube
2. Screen retainer units
3. Silica gel charge

Operations:

1. Bead both ends of tube for screen retainer units.
2. Fill with silica gel charge and assemble screen retainer.
3. Spin both ends closed.

Perhaps you are producing a part that *can* and *should* be redesigned to effect savings in cost and materials and ultimately give higher efficiency in operation. Would you like to have one of our engineers discuss these possibilities with you? No obligation, of course. Your letterhead will bring you a copy of our new brochure on our spun end process. Send for it; no charge.

WOLVERINE TUBE DIVISION
Calumet and Hecla Consolidated Copper Company, Inc.
MANUFACTURERS OF SEAMLESS NON-FERROUS TUBING
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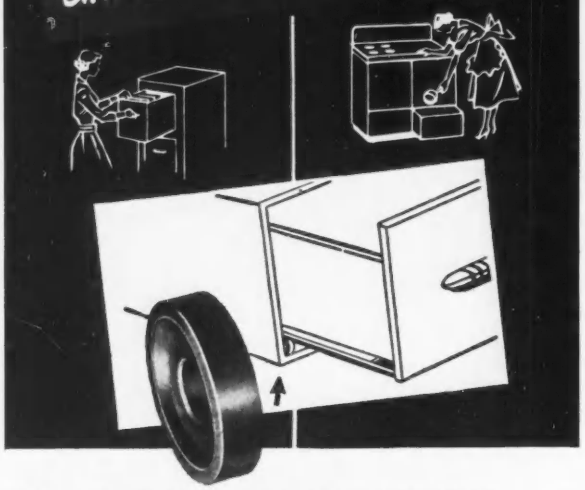
Another Contribution to Industry through Powder Metallurgy by BOUND BROOK

YOU 3 MONEY-SAVING SINGLE "POWDIRON"



FOR EXAMPLE, DRAWER ROLLERS

CHECK these important benefits:

1. continuous lubrication between the shaft and roller.
2. smooth turning rollers, easy to assemble, without time-consuming machining.
3. no messy oil drips on cooking utensils or important filed data.

drawers that work . . . all the time . . . with ease

BOUND BROOK "POWDIRON" bearings and structural parts are:

- made from pure metal powders
- die-formed to shape
- alloyed at high temperatures
- finished to precise dimensions, AND
- vacuum-impregnated with lubricant

CONSULT OUR ENGINEERS

BOUND BROOK "COMPO" • "POWDIRON" • BOUND BROOK

Research Foundation, Illinois Institute of Technology, Chicago, Illinois, has all the dope on the thermocouples. Dr. Karl Lark-Horovitz, of Purdue University, Lafayette, Indiana is the person to write for data on germanium.

We are happy that Mr. Nielsen thinks so highly of the "Highlights" section.

Right Church, Wrong Pew

To the Editor:

I would like to call to your attention an error that appeared in the Reference Book Sheet on page 159 of the March issue. This data sheet accompanies my article on "Styrene Plastics" appearing in the same issue. The material whose trade name is "P-8", produced by the Koppers Company, is shown in the table as a "modified" styrene. It should have been listed under the heading "Unmodified".—S. E. GLICK

Monsanto Chemical Company

Fluorine Seals

To the Editor:

We would sincerely appreciate your cooperation in assisting us to obtain a listing of manufacturers who are presently moulding "O" rings and "V" packings from the various new fluorine plastics as described in Mr. Rubin's article appearing in the May issue of PRODUCT ENGINEERING.

—E. F. BRUNING

The Bruning Company

Ed—The V-packings are molded by Linear, Incorporated, Camden, New Jersey; and the O-rings are made by Plastic and Rubber Products Company, 2100 Hyde Park Blvd., Los Angeles 47, California.

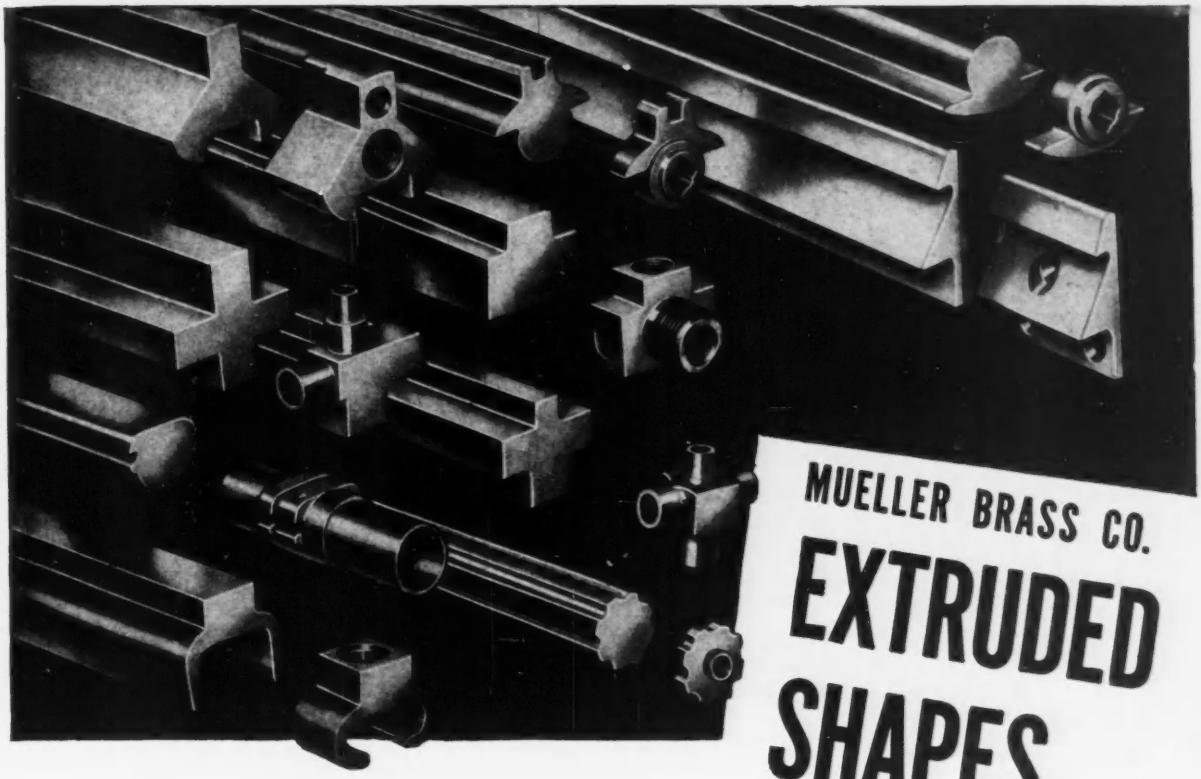
Multi-Stylus Recorder

To the Editor:

We would appreciate your help in locating several manufacturers who market an operation recorder using an electro-sensitive paper. Our application requires four to forty stylii per unit, a chart speed of one-inch per hour, and an operating cycle of approximately one hour in 24 hours.—M. T. NANCE

Shell Oil Company

Ed—The following three companies are possible suppliers: Esterline-Angus Company, Incorporated, P. O. Box 596, Indianapolis, Indiana; Electro Medical Laboratories, Holliston, Massachusetts; and General Railway Signal Company, Peoples Gas Building, Chicago, Illinois.



MUELLER BRASS CO.

EXTRUDED SHAPES...

can lower your production costs!

REDUCE MACHINING OPERATIONS—LESS WASTE—The extruded shape is similar to the shape of the finished product, in some instances merely requiring a milling and drilling operation to complete the finished article.

SAVES TIME—Surfaces are extruded to precision tolerances and to a mirror-like smoothness. Less time is required for buffing and polishing in preparation for final plating.

LESS SCRAP—The sound, dense, fine-grained structure of the metal and absence of porosity result in less rejects, especially where parts must withstand internal pressure.

LONGER TOOL LIFE—Machinability is better—tools last longer and require less grinding, thus permitting steadier production runs.

A GREAT VARIETY OF SHAPES AND ALLOYS

The illustrations shown above, of extruded rods and their finished parts, are but a few of the many thousands that can be produced; but they give a general idea of the variety of shapes available.

Do you want more efficient production or better performance of your product? A specially processed rod may be the answer. If you have a problem, please tell us about it, our Technical Engineers and Laboratory are at your disposal.

YOU CAN PIN MORE PROFIT TO YOUR COST SHEET

Mueller Brass Co. Red Tip Brass Rod is a universal, many-purpose, extra-fast cutting Rod. Its constant uniformity saves tools, grinding and "down" time. It actually can be machined at greater speeds than that of which any machine is capable on a continuous production basis. YOU CAN PIN MORE PROFIT TO YOUR COST SHEET BY USING MUELLER BRASS CO. BRASS ROD AND EXTRUDED SHAPES.

MUELLER BRASS CO.

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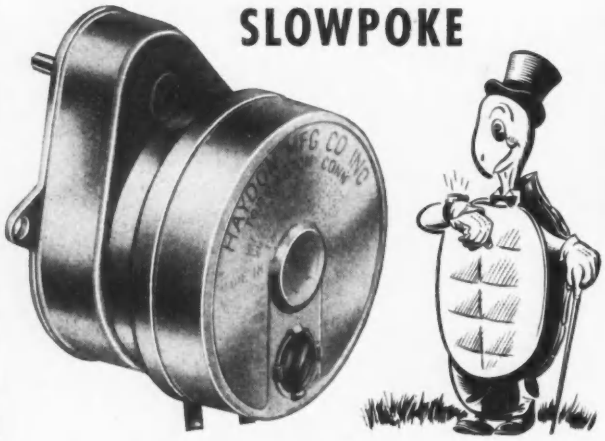
Timing Ideas

HERE'S A COMPACT SLOWPOKE



Designers and manufacturers concerned with the excessive space requirements and high cost of external reduction gearing will welcome this new slow speed timing motor. The series 4400 requires minimum space and provides, at comparatively low costs, speeds from 6 hours to 7 days per revolution. The careful design, expert engineering and precision manufacture, are advantages common to all Haydon motors.

SUPERIORITY FEATURES

DEPENDABILITY: Slow 450 rpm rotor speed means less reduction gearing and fewer fast wheels, providing quieter operation and longer life.

SMALL SIZE: Smallest available of this type.

TOTAL ENCLOSURE: A basic feature of sound design.

CONTROLLED LUBRICATION: Separate rotor and reduction gearing lubricating systems permit selection of best methods and lubricants, control circulation, insure against leakage.

OPERATING POSITION: Operates continuously in any position.

SIMPLE, SECURE ASSEMBLY: Entire face of motor can be supported securely against mounting surface. Motor leads standard for quick, inexpensive wiring.

STANDARD INTERCHANGEABLE DESIGNS: Speed from 300 rpm to 1 revolution per week in only 2 interchangeable motor series.

For complete design and engineering specifications, write for catalog: Timing Motors No. 322 — Timers No. 323 — Clock Movements No. 324. Yours without obligation.

HAYDON AT TORRINGTON

HEADQUARTERS FOR **TIMING**

HAYDON Manufacturing Co., Inc.

3131 ELM STREET

TORRINGTON, CONNECTICUT

SUBSIDIARY OF **GENERAL TIME** CORPORATION

NEW BOOKS

Supersonic Aerodynamics
A Theoretical Introduction

EDWARD R. C. MILES, *Research Mathematician, Institute for Cooperative Research and Lecturer in the School of Engineering, The John Hopkins University. 255 pages, 6 x 9 in. Published by the McGraw-Hill Book Co., Inc., 330 W. 42nd St., New York 18, N. Y. $4.*

This is one of two books recently published by McGraw-Hill on Supersonic Aerodynamics. The theoretical discussion is primarily intended for senior and graduate engineers in aeronautical engineering universities, but it is also suitable as a primer for any engineer who desires to build up his background of advanced fluid dynamics.

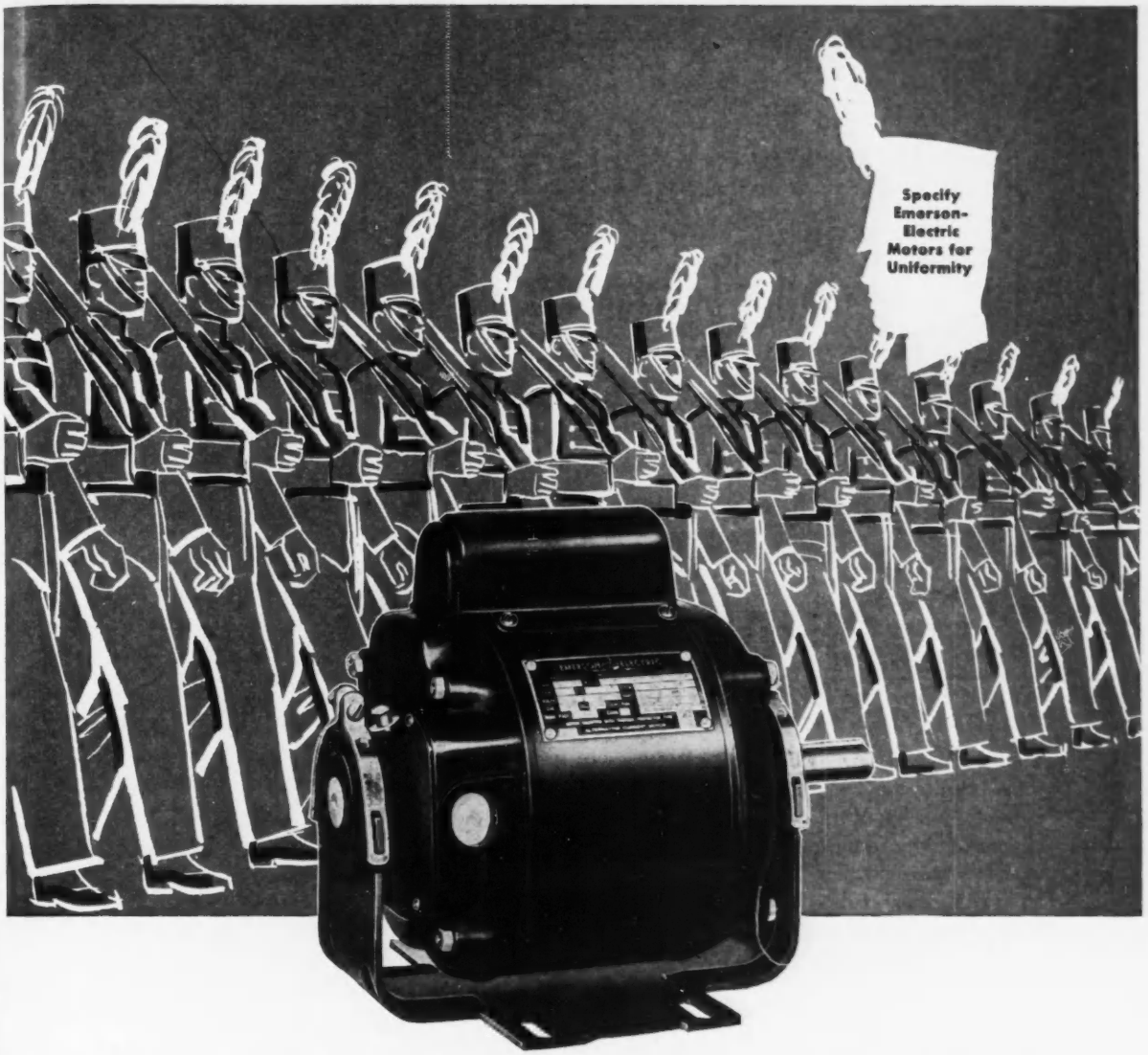
Perhaps the basic function of the book is to help the reader build a background for further theoretical investigation, as well as an understanding of current technical literature. As a result, the book starts with fundamental theory and progresses through eleven chapters to subjects such as comparison of adiabatic and shock flow.

Chapter 1 is concerned with Fundamental Theory, and includes such subjects as perfect gases, change of state, Bernoulli's equation, Mach number, and equations of fluid motion.

Chapter 2 is on Divergence and Circulation. It deals with vector fields, transformation from rectangular to polar coordinates, the equation of continuity and circulation in three dimensions.

Other chapters, 3-11, are concerned with the following: The Potential Equation; Characteristics in the Plane; Linear Theory of Plane Flow; The Linear Potential Equation in Three Dimensions; Shock Waves; Cones in Supersonic Flow; The Method of Characteristics for Axially Symmetric Supersonic Flow; Potential Flow in the Hodograph Plane; and as previously mentioned, Comparison of Adiabatic and Shock Flow in Two Dimensions.

Primarily the book is a theoretical development of mathematical formulas and equations for determining fundamental characteristics of supersonic flow. The nature of characteristics curves is fully treated to prepare the reader for graphic applications, and a large number of problems, primarily



Each Motor Uniform in Appearance and Performance

Cadets on parade present a precise, uniform appearance, but under their caps they are individually different.

In electric motors, however, uniformity in appearance is not enough—uniformity of *performance* is the true measure of their worth. The fact that Emerson-Electric Motors are uniform in performance is no coincidence, for behind each one stands a pioneer motor manufacturer with 60 years of engineering, and precision production experience.

Your products, too, demand this same uniform performance in addition to identical standards of appearance. It will pay you to consider Emerson-Electric Motors for the vital job of powering your product with unvarying efficiency and dependability.

Your inquiry is invited. Learn about the many advantages of Emerson-Electric Motors, 1/20 to 5 h.p.

THE EMERSON ELECTRIC MFG. CO.
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Emerson-Electric's unique *Twin-gineering* SERVICE solves your power problems

Experienced Emerson-Electric Engineers are eager to collaborate with your own staff in designing and providing the proper motor application to your new or improved appliance or equipment. Such collaboration—TWIN-GINEERING we call it—can save you costly engineering "back-tracking," and may suggest short cuts or improvements of great competitive benefit to your product. Write us today for Free bulletin No. 356.

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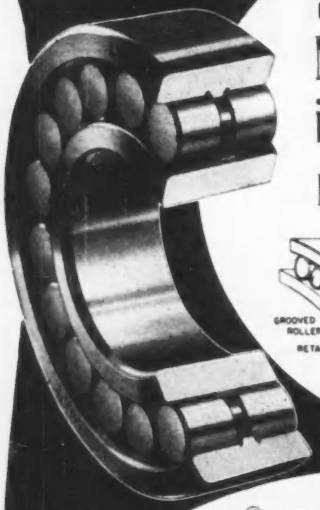
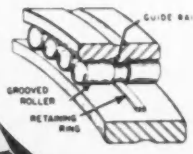
another FIRST in
McGILL precision bearings

a
NEW PRINCIPLE
in
roller bearing design

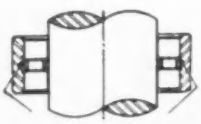




Rollers cannot skew. A guide rail integral with the outer race maintains alignment of the grooved rollers.

The NEW McGILL® GUIDEROL roller bearing

The Bearing with the Self-Aligning Rollers — a simplified roller bearing construction that automatically corrects roller skewing — without space wasting cages! Perfect roller alignment with resulting superior performance is maintained by this new principle of guided rollers. Even with reduced internal radial looseness a GUIDEROL bearing overcomes any tendency to bind under limited misalignment. Produced in needle and cylindrical type roller bearings. Write for information packed Bulletin today.



UNIVERSAL MOUNTING

Universal Mounting — from horizontal to vertical is possible. No cocking of rollers on vertical shafts because the grooved rollers are located by guide rail.

OPEN ENDS — SELF CLEANING

Open Ends — Self cleaning in applications permitting free circulation of oil or grease. Open faces set up flushing action inside the bearing.

GREATER ANGULAR RIGIDITY

Greater Angular Rigidity is provided by longer rollers that permit race and roller contact virtually to the outside edges of the races.

Write for your copy of the new GUIDEROL Bearing Bulletin No. GR-50. Address: McGill Manufacturing Co., Inc., Bearing Division, 201 N. Lafayette Street, Valparaiso, Indiana.

McGILL® precision bearings

intended for the classroom student, are included. These problems range in difficulty from simple numerical ones to substantial theoretical analyses and should prove useful to the industrial reader who is concerned with checking his understanding of the text by working out the problems. Some sample problems are worked out in the text to better impress on the reader the method of attack. Line drawings and diagrams have been substituted for photographic illustrations throughout the book, because a theoretical discussion on an advanced subject of this type cannot be helped by the use of photographs as the only supplement to the text.

Stainless Steel Structural Design

MICHAEL WATTER, *Director of Research, The Budd Company and* R. A. LINCOLN, *Allegheny Ludlum Steel Corporation.* 153 *pages,* 7½ x 10½ *in. Published by the Republic Press, Pittsburgh, Pa.* $5.

This book describes a design procedure for calculating the allowable loads for structures made of stainless steel. This procedure was developed and simplified by many applications at the Budd Company. Based on experience and testing at the Allegheny Ludlum Steel Corporation, it has proven very satisfactory. However, an important phase of design is knowing the properties of the material. Pertinent data are also presented which describe the physical properties of high-tensile, stainless steel strip.

A number of structural materials do not display a well-defined region of transition from elastic to plastic range. Stainless steel is one of such materials. Its stress-strain curve exhibits a typical behavior of having an initially straight portion beyond which the rate of elongation increases gradually. In modern design of lightweight structures, the criterion of yield stress is very much subordinate to the requirements of elastic stability. High-tensile, stainless steel strip, with excellent properties of extreme toughness and energy absorption combined with high ductility, make it one of the exceptionally desirable structural materials.

Practical engineering methods are listed for determining the stresses in stainless steel structural elements. Considerable data are presented which apply to the behavior of columns. Included are charts of the combined or reduced moduli used in the calcu-

Quality that saves money...that's why

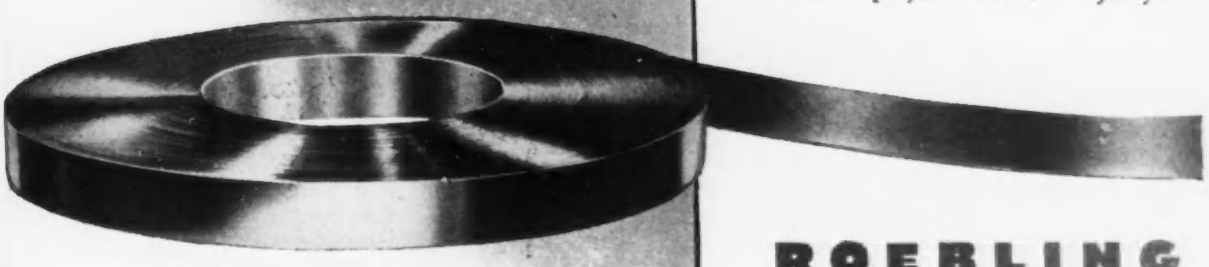
Today it's Roebling!

for Cold Rolled Spring Steel

JUST PUT IT on one basis . . . *dollars and cents!* If you cut down preparation time, you save money. If you cut down machine stoppages and rejects, you save still more. And you'll make *all* these savings with Roebling Cold Rolled Spring Steel because it's dimensionally accurate . . . absolutely uniform in physical properties and structure . . . one inch just like every other inch.

Roebling Cold Rolled Spring Steel is available annealed, hard rolled untempered; scaleless tempered; tempered and polished; tempered, polished and strawed, or tempered, polished and blued.

Have your Roebling Field Man help you select the cold rolled spring steel—or the round, flat or shaped wire—that will help improve both your product and your production, and give you genuine economy. John A. Roebling's Sons Company, Trenton 2, New Jersey.



Roebling has one of the largest specialty wire mills in America. Special techniques and the most modern precision machines assure a product that brings you faster, smoother operation.

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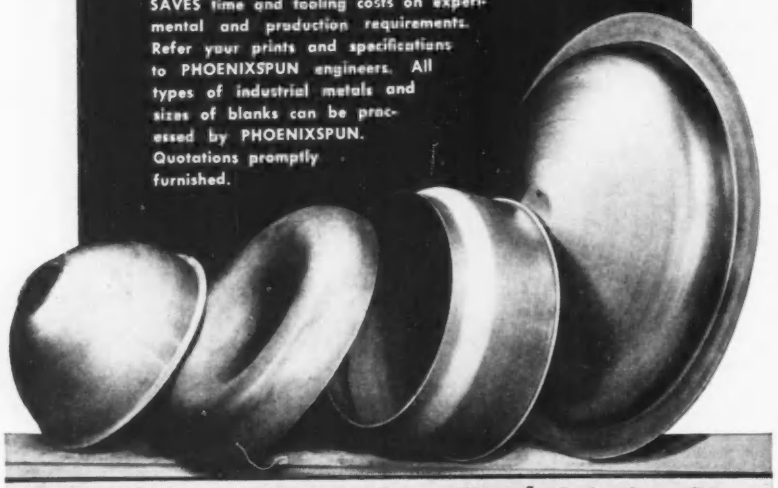

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lation of compression members which are stressed beyond the proportional limit. Many equations and charts are given to simplify the calculation of loads that flat plates and cylindrical members can support. In addition, there are several examples where composite columns are calculated to illustrate how the basic plate and cylindrical data can be used. Finally, bending beyond the proportional limit, the shear buckling of flat sheets, and torsional instability of open-section columns are discussed.

Plane and Spherical Trigonometry

CLAUDE IRWIN PALMER, CHARLES WILBUR LEIGH, SPOFFARD HARRIS KIMBALL. *Fifth Edition.* 370 *pages,* 6 x 9 *in. Published by The McGraw-Hill Book Co., Inc.,* 330 *W.* 42*nd St., New York, N. Y.* $3.25.

This fifth edition was prepared in the belief that a book that has been a leading text in trigonometry for thirty-five years must be fundamentally sound in all major respects. Changes in the text, therefore, were made only after very careful consideration. The order of topics has been maintained.

The treatment of graphical representation has been altered in order to give a somewhat greater emphasis to the curves and less to line representation. Many problems have been replaced and new numerical data are used in others.

The section on logarithms and the use of trigonometric tables has been made the final chapter. Five-place logarithmic and trigonometric tables are presented in an appendix consisting of 102 pages.

Mechanical Wear

Edited by JOHN T. BURWELL, *Associate Professor, Massachusetts Institute of Technology.* 387 *pages,* 5¾ x 9 *in. Published by the American Society for Metals,* 7301 *Euclid Ave., Cleveland, Ohio.* $6.50.

This book consists of a series of papers that were presented at a special conference held at the Massachusetts Institute of Technology, in June, 1948. The papers cover laboratory as well as service experience on wear in internal combustion engines, steam turbines, brake materials, journal bearings, gears, turbine blades and cutting tools. As a result, this book contains the most up-to-date information concerning the

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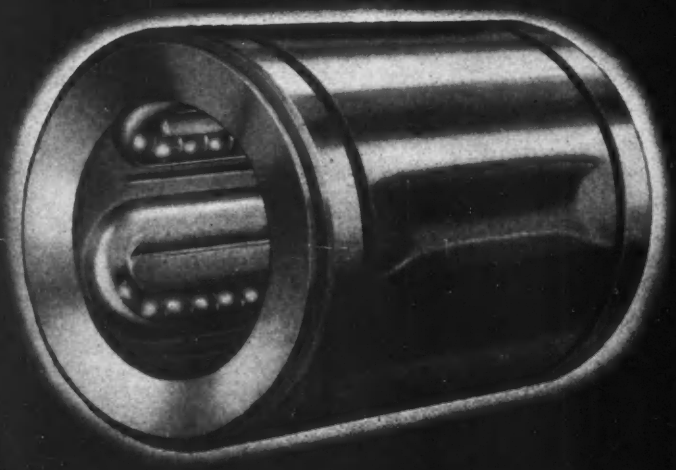

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general phenomena of wear in its many and varied forms. The book is particularly appropriate at this time since the problem of mechanical wear and means of curing this fault is becoming more important in modern industry where the need for increasing power output and transmission has become more urgent.

Some of the subjects covered are: Wear in diesel and automotive engines; wear as affected by various conditions of lubrication; wear of gear teeth including the effects of the viscosity of oil. Recent data are presented on the endurance limit of materials as determined by roll tests and the influence of hardness. The wear of metals in contact with refractory materials is discussed, and, in addition, the friction and wear of some powdered metal bronzes are described. The subjects of cavitation erosion by liquids and the wear of electric current contacts are not considered.

The discussion by well-known authorities following the presentation of the papers makes each subject quite complete. Most of the material is clearly written, and supplemented with many graphs and photographs. There is a bibliography at the end which is keyed to each particular paper.

Engineering Supersonic Aerodynamics

E. ARTHUR BONNEY, *Project Supervisor, Aerodynamics and Control Group, Applied Physics Laboratory of the Johns Hopkins University.* 264 *pages,* 6 x 9 *in. Published by the McGraw-Hill Book Co.,* 330 *W.* 42 *St., New York* 18, *N. Y.* $4.

While this new publication is intended as a college text, it is aimed, too, at the industrial engineer in industry. The purpose of the book is to present the basic information on supersonic aerodynamics that is necessary as background material for every aeronautical engineer. Particular emphasis has been placed on presenting practical applied information that would be desired by the engineer in understanding the principles of the subject and the necessary examples in designing and the performance of supersonic aircraft. According to the author, the book avoids specialization on the mathematics of any particular branch of the subject, and is intended not as a reference text for specialists, but as an introductory course in supersonic aerodynamics. It is somewhat less advanced in theory than the book previously discussed, but contains more practical data on application. The two

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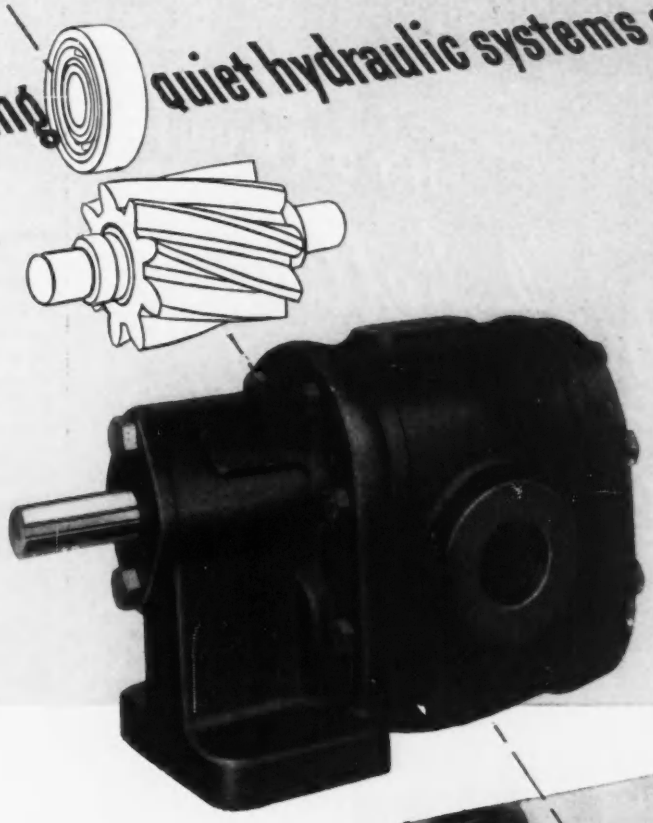

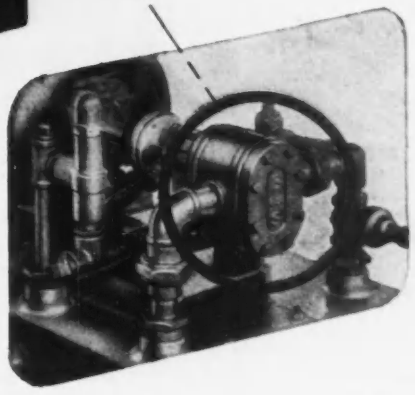

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texts supplement each other very well.

Chapters include Compression and Expansion Waves; One-Dimensional Flow—Nozzles and Diffusers; Two-Dimensional Characteristics; Airfoil Characteristics; Bodies of Revolution; Supersonic Wind Tunnels; and Composite Design and Performance. As with the previously discussed volume, this one relies primarily on line drawings, sketches, and charts to get across the information, and several comprehensive tables are included.

Both this book and the previous one are rather specialized in their field of coverage and are aimed primarily at aircraft and guided missile designers. As such, the average product design engineer will not find them too useful, unless he is concerned with background on this particular subject.

Essentials of Electricity For Radio and Television

MORRIS SLURZBERG *and* WILLIAM OSTERHELD, *Instructors of Electricity, Radio and Television, Wm. L. Dickinson High School, Jersey City, New Jersey. 6 x 9¼ in., 533 pages. Published by the McGraw-Hill Book Co., Inc., 330 W. 42nd St., New York* 18, N. Y. $5.

This new book is a revision of *Electrical Essentials of Radio* published six years ago. The scope of the second edition, has been extended to cover the electrical fundamentals necessary for further study of frequency-modulation, television, high-fidelity circuits, and high-frequency circuits. It deals with the electrical principles pertaining to radio and television rather than power circuits and develops the presentation of electrical principles in terms of electron flow. This disposes of the confusion concerning current flow versus electron flow, and thus conforms to the accepted usage of electron theory in analyzing electric and electronic circuit components and circuit action.

The discussion of sound is expanded to include additional pinciples necessary to a thorough understanding of high-fidelity transmission and reception as used in better a-m, f-m and television receivers.

Also revised and expanded is the treatment of Kinds of Electric Current to include descriptions of interrupted and complex currents as used in television and electronic circuits. The chapter on Fundamental Electric Units now includes a description of the new standard units of volt, ampere, and ohms as adopted in 1948. Many other changes serve to bring this

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An extensive appendix containing thirteen sections provides reference data and information for solving the problems in the text.

Gear Cutting Practice

FRED H. COLVIN *and* FRANK A. STANLEY. *Third Edition.* 532 *pages,* 6 x 9 *in. Published by the McGraw-Hill Book Co.,* 330 *W.* 42*nd St., New York* 18, *N. Y.* $4.75.

Intended for machinists and shop men in the gear manufacturing industry, this book should also serve the engineer who may be engaged in some phase of gear work. There is considerable information for those who require background in gear design and manufacture. It should serve the engineer as a reference book, for many problems which arise in the performance of gear drives can be better understood and possibly solved by having a good understanding of the methods of manufacture.

In revising this book, the authors have added a large amount of up-to-date information. The most important of these are methods of gear inspection and equipment, finishing gear teeth, methods of bevel gear manufacture, and data on involute splines. The chapter on heat treatment discusses various ways of hardening gear teeth and also discusses the problem of distortion from quenching.

To make the information more readily available, the book is divided into eleven sections. Over two hundred illustrations and many reference tables help make this book a useful

Sales Engineering

BERNARD LESTER. *Second Edition.* 226 *pages,* 5½ x 8½ *in. Published by John Wiley and Sons, Inc.,* 440 *Fourth Ave., New York* 16, *N. Y.* $3.

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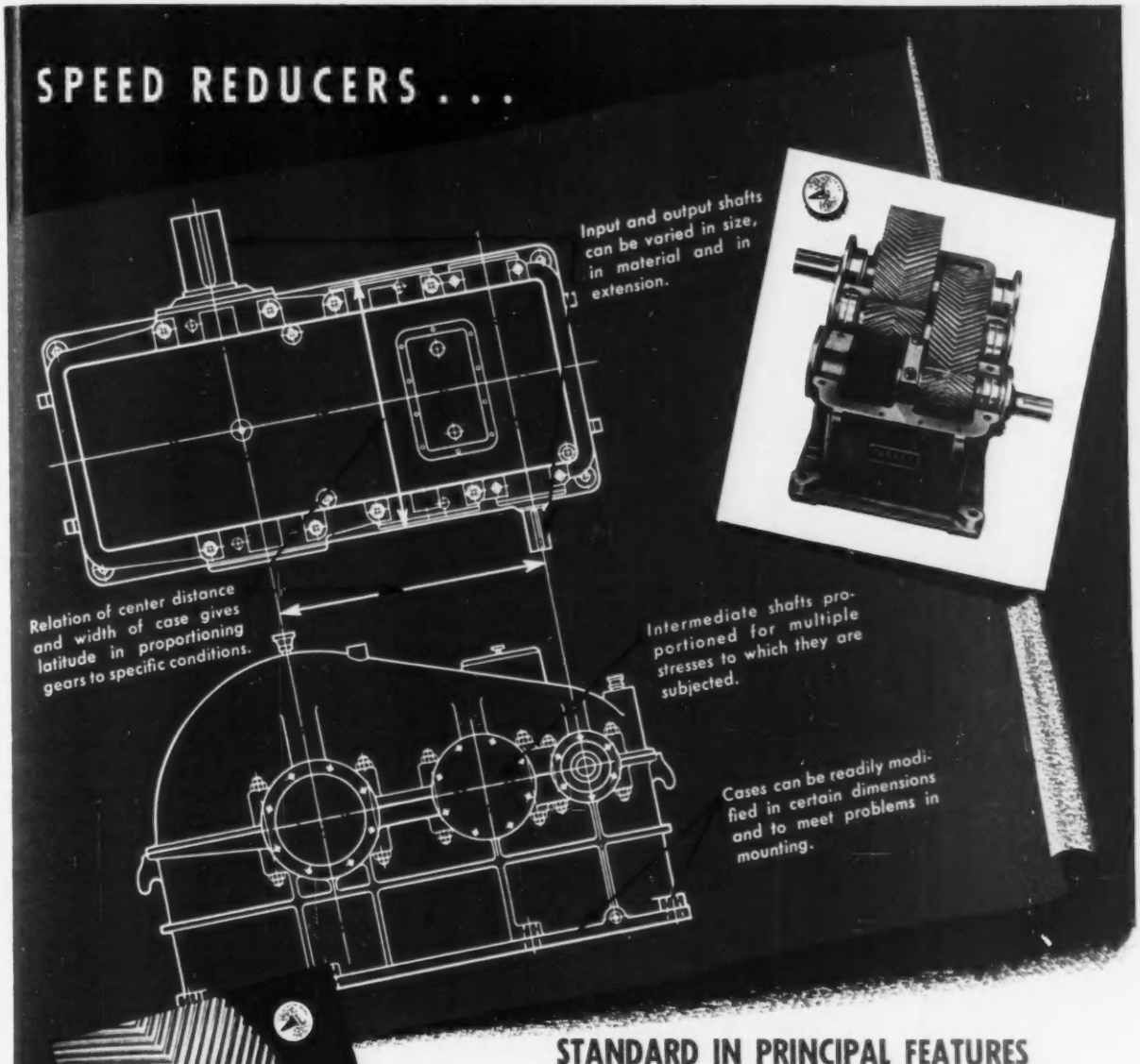
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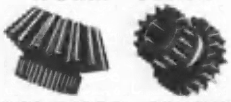

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services, the function of the sales engineer becomes more important. Under these conditions, he must constantly be alert for new ideas and improved selling methods. This book should be very helpful for it contains the extensive experiences of the author. The material should be particularly appealing to the young engineer for it describes the work done by the sales engineer and the opportunities that exist for his services.

Many aspects of sales engineering are discussed. The most important are: Market analysis, Product characteristics and Purchasing methods. The performance of the sales engineer is analyzed by observing various sales procedures. Planned interviews are emphasized along with many devices which should be used to increase sales.

The book is full of interesting anecdotes that are taken from the author's own experience to emphasize an important point. These also serve to make the book much easier reading.

Kent's Handbook

Design and Production Volume

Edited by COLIN CARMICHAEL, *Editor, Machine Design. Twelfth Edition,* 1660 *pages,* 5½ x 8⅜ *in. Published by John Wiley & Sons,* 440 *Fourth Ave., New York* 16, *N. Y.* $8.50.

Kent's Handbook has always enjoyed a good reputation—and deservedly so. When William Kent originally got together the first edition, he used as the cornerstone for the book practical engineering data and information that he had been collecting for more than 20 years. The original volume was a practical, easy to use reference. The present edition is even more so, because some sections have been cut, others expanded, and the entire volume revised for maximum usefulness.

William Kent had nearly completed the preliminary planning for the present edition prior to his death in 1947. The new editor of this volume is Colin Carmichael, who, as editor of Machine Design is well qualified for the job.

One of the most significant changes in the new volume is the title Design and Production, instead of Design, Shop Practice, as this section previously was called. The new title emphasizes the idea that design and production are, in reality, two phases of a single activity—the engineering of a product from the inception of an idea to the completion of the finished article at an economical cost.

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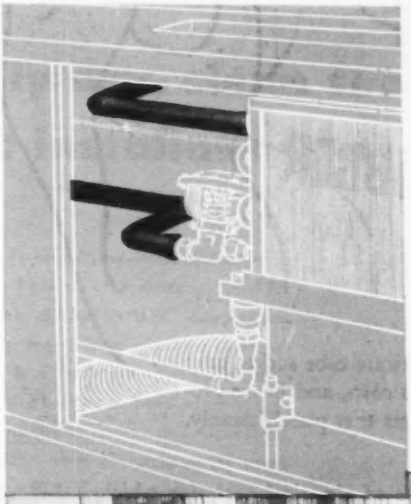

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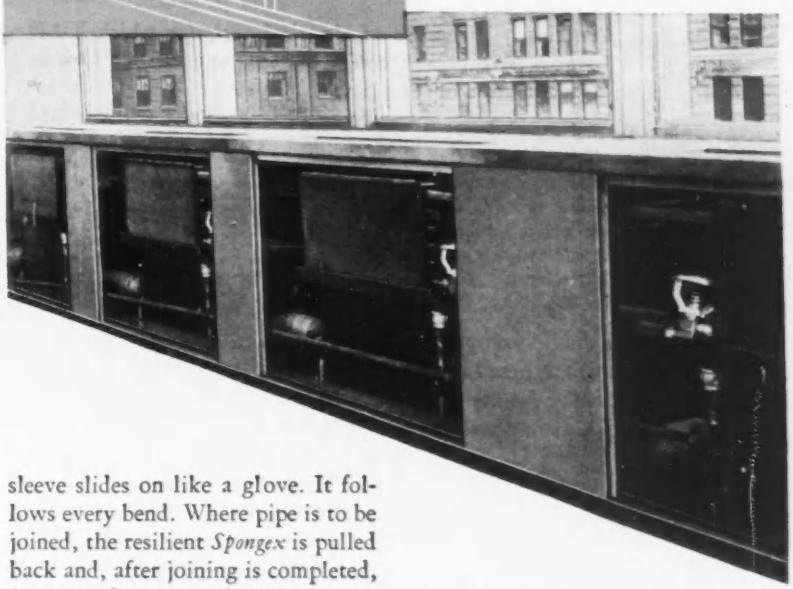

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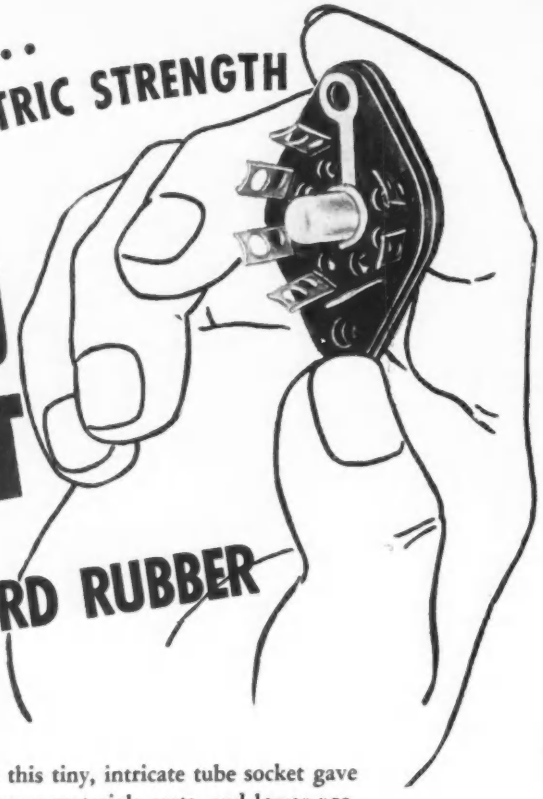

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engineers. J. O. Almen, Allen H. Candee, S. Leroy Crawshaw, Hans Ernst, Robert O. Fehr, J. C. Fox, E. L. Hemingway, E. F. Riesing, Arthur F. Underwood, and A. M. Wall are a representative sample of the group. All are specialists; each has written on a particular phase of the design and production problem. They represent, respectively, the Research Laboratories Division of General Motors, The Gleason Works, Western Gear Works, The Cincinatti Milling Machine Company, The General Electric Company, Doehler-Jarvis Corporation; Gisholt Machine Company, Firestone Tire and Rubber Company, the Research Laboratories Division of General Motors Corporation, and the Research Laboratories of Westinghouse Electric Corporation.

The general classification of sections can be broken down as follows:

SELECTION OF MATERIALS: General Properties of Metals and Alloys; Iron and Steel; Corrosion and Corrosion Resistance; Non-ferrous Metals and Alloys; Carbon and Graphite; and Fabricated Materials.

DESIGN PRINCIPLES: Mechanisms, Mechanics, and Machine Elements; Static Stresses; and Vibration and Noise Control.

DESIGN AND SELECTION OF MACHINE COMPONENTS: Fasteners; Mechanical Springs; Bearings and Lubrication; Machine Hydraulics; Gearing; Shafts, Keys, and Splines; Electric Motors and Their Control; Automatic Regulators; and Pressure Seals.

PRODUCTION PROCESSES: Iron and Steel Casting; Plastic Working of Metals; Joining of Materials; Industrial Heating Processes; Metal Cutting Processes; Dimensional Control; and Woodworking.

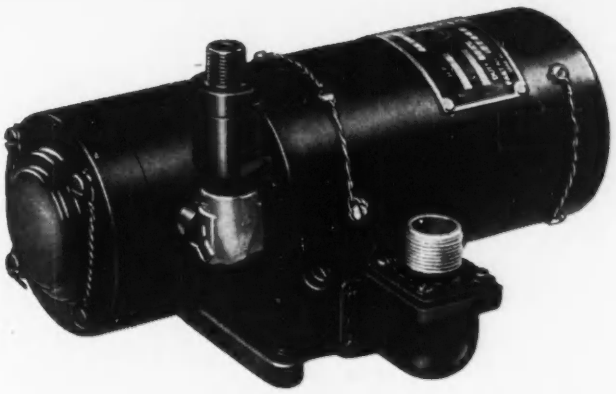
PRODUCTION PLANT EQUIPMENT: Hoisting; Production Plant Construction and Equipment.

MATHEMATICAL TABLES.

Strength of Materials

JAMES E. BOYD, *Emeritus Professor of Mechanics, revised by* SAMUEL B. FOLK, *Emeritus Professor of Mechanics, The Ohio State University.* 417 *pages,* 6 x 9 *in. Published by McGraw-Hill Book Co., Inc.,* 330 *W.* 42*nd St., New York* 18, *N. Y.* $4.

In the new revision of this successful text, a conscious attempt is made to emphasize the fundamentals of the theory and to accept the process of analysis in the application of mathe



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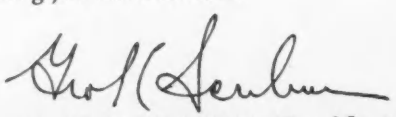

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